

The Earth Beneath our Feet

Geological History and Mindfulness of our Bond with our Planet

Second Edition



Antón Bousquet

The earth may be seen as a mere foundation of our world, a rigid basis upon which we can live, stand, and build. It may also be considered a provider, the source of the crops we grow and a vast reserve of resources to be exploited. More than this, our planet is also a celestial body, continuously shaped by the heavens, and the story of its formation and evolution is tightly intertwined with the story of life itself. To become familiar with this story is an opportunity to better understand our surroundings, and also our origin, as products of the various events it went through. The first part of the present book offers a retelling of this fascinating story of the earth, one based on the current scientific knowledge provided by geologists, yet strongly inviting a meditation on each of its chapters, a mindful experience of how each event reverberates through us and our environment.

Furthermore, to better know the earth is to more deeply understand our body, as every single part of it is made from its substance. Continuously circulating, from the ground to living beings and to the air, the elements forming our flesh and bones only temporarily pass through us. They always remain part of our planet, and therefore, we inextricably belong to it. The second part of this work will present the paths taken by a selection of these elements and compounds playing crucial roles in the machinery of the body, while still focusing on a mindful experience, the weaving of new bonds between these substances and us. This may allow us to transform our vision of the matter that forms our body, the same matter found all around us, in the soil or in the air. These two journeys may perhaps then become the starting point of a personal practice, a new relationship with our marvelous planet, which may be life's only home.

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Abbreviations

Ch.	Chapter.
M.y.a.	Million years ago.
TBA.	Translation by the author.

Introduction

Remain true to the earth, and do not believe those who speak to you of superterrestrial hopes!¹

— Friedrich Nietzsche

Life was born in a watery cradle, the ocean, and soon after, it turned itself toward the blazing face of the sun, seeing in it a vivifying spring of warmth and light, an impulse to power its growth, and then, after a while, a source of illumination, revealing a nascent world. It painstakingly crawled out of the shallows, conquering the dry land, and later made the air enshrouding the planet its inalienable dominion, flying through it and touching the very edge of space. So enthralled by the incomparable power of our star, we see our future as inscribed in the celestial vault, in the dabs of light on its velvety canvas, with the naive attempting to decipher the movements of constellations as a crude means of divination, while the perspicacious seeks a new world to explore and colonize. So enraptured by the display of the gigantic wheels of the skies, man directs his hopes and his efforts toward the enterprise of a severance from the earth that begat him. Before losing oneself in an imaginary vision of a possible new home for life, one should nevertheless first begin to perceive what this first home of life truly represents. Only then, when the truth of the earth will have been allowed to shine into the innermost layers of our hearts, can we begin to see ourselves durably departing from it.

To remain true to the earth is to remain true to ourselves, real-

¹Translation by the author. Original German: “Bleibt der Erde treu und glaubt denen nicht, welche euch von überirdischen Hoffnungen reden!” From: Nietzsche, Friedrich. *Nietzsche's Werke Bd. 4. Morgenröthe*. Leipzig Kröner, 1917. Page 13.

izing that we are more than mere dwellers of the earth, but rather are fully part of this tangible realm. Every single particle of our body is more ancient than our species, and they, with only rare exceptions, such as chunks of matter suddenly fallen from the sky, all came from the furnace of the abyss under our feet. Our substance is made of innumerable specks of earth, extracted from the ground by life, or ejected into the air by the unpredictable whims of the planet itself. Even if our species one day succeeds in making another celestial body its new home, our nature will forever have been marked by the heavy imprint of this planet, with its peculiar composition, reflected in every cell that makes us who we are. Until then, we nonetheless remain firmly attached to the ground, with the weight of this wide globe of rocks and metals being sufficient to prevent us from escaping its grip. To send a single soul beyond the reach of this attraction of the earth demands a considerable amount of effort and resource, and thus, for the foreseeable future, we will remain earthbound, tethered with an invisible thread to the first abode of life, forced to rein in our ambitions and to take care it, encouraging a responsible attitude toward our environment, vital if we are to perdure on this planet.

Furthermore, to be true nonetheless also requires an understanding of the nature of truth itself, and this is something that cannot be found upon the earth as such, but rather only in man's world. For us to be true to the earth, and to ourselves as earthly beings, we shall not merely live our days as any other man present on the face of this planet, busying ourselves with the affairs of the world while appropriating the wealth of the planet. We shall use the resources of the world, knowledge and science, to deepen our understanding of the dwelling place of life, our sole refuge in the dark emptiness of space. Going against the flow of the world, we shall use the man-made realm to tighten our bond with the one below. Then, when our personal experience of our materiality will be deeply intertwined with a profound awareness of the nature of our surroundings, is when the truth of the earth may begin to shine in our eyes, and be felt through all of our other senses, passing through all the gates of our perceptions. Such an awareness nonetheless implies a comprehensive vision of what our planet is, beyond the phenomenon of our own presence, beyond the frontiers of our narrow experience.

To envision the truth of the earth, one's gaze must transcend the natural boundaries placed upon our bodies. We must peer into the distant past, long before we first saw the light of day, simply

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to comprehend the origin of our planet, what it is made of, and how it took its present form. This represents an exploration of the linear dimension of the earth, seeing it as a physical object caught in the torrent of time, patiently shaped by the heavens. This story is one whose unfolding began billions of years ago, tightly braided with that of life, which began soon after, and it will be the subject of the first part of the present work. Appropriating the invaluable discoveries made by the generations of learned men who have preceded us, people endowed with a peculiar curiosity pushing them to excavate the past of our beloved home, its origin will be recounted, as will each major milestone of its history. The focus of each tale of the earth, each chapter, will nonetheless not be a detailed historical or geological analysis. After a brief exposition of the nature of each milestone of the planet, the heart of the matter will be the fostering of an experience, the creation of a peculiar bond between our consciousness and this remote event. A mindfulness of the story of the earth is indeed key to the fostering of a deeper appreciation of our surroundings and of our own being, as creatures occupying the face of the earth, something that holds a greater potential of transforming our existence than lengthy scientific descriptions and analyses. The weaving of such a personal bond, the fostering of an individual experience, is necessary because the truth of the earth cannot simply be known with mere words, even though words are useless to take the first step toward such an experience. Marrying knowledge and experience, words and sensations, this is when the truth that belongs to neither can be touched with the tip of one's fingers, and seen as a distant mirage on the horizon, a fleeting and yet profoundly enlightening vision. Linking the grandiose story of this celestial body with the combination of our senses and our consciousness, letting us feel our body as fully part of this unfolding, shaped by each one of its tales, each one of its chapters, this revelation may then become an inextricable part of us, constantly present, deeply affecting our relationships, not only with the earth, but with everything earthly, such as the world and each creature inhabiting it.

The linear story of the earth represents the broad strokes of its passage through time. It recounts a global vision of the planet, a glimpse that extends to the depths of a distant past, a considerable length of time, but necessarily overlooks the finest details of this grand adventure. It can nonetheless be completed by another point of view, one focusing on the various chemical elements of which the earth is made. The peculiarity of this second story is its circular na-

ture, contrasting with the linearity of the first one. Such elements, such as oxygen, iron, or calcium, indeed are not only carried by the planet through the course of the torrent of time, they are also taken on a permanent journey throughout the different strata of the greater earth: the depths of the mantle, the crust, the ocean, life, and the air. This journey is a more or less convoluted loop, a cycle that is endlessly repeated, even though these elements never take exactly the same path. The second part of the present work will be devoted to a description of such a voyage of ten of these elements or compounds, carefully chosen for their importance in our existence, as the path of each one of them passes right through our body, and they are all vital to us, creatures willing to remain among the living. Following the circular path of these bits of matter that are also part of life, we are offered a chance to consider the nature of our materiality, our earthiness, as we can contemplate the arrival and the departure of such grains of matter from our flesh, seeing them elevated in the sky, or returning to the abyssal depths of the rocky ground. A more limpid view of the composition of our body and of the constant flow of the substances it is made of, passing through the soil, the seas, and the sky, can lead us to see the environment around us as more than a mere background surrounding us, but rather as an inextricable part of ourselves, just like we are part of it, blurring the contours of our skin, the boundaries of our being, as we are like Theseus' s ship, continuously renewed, each part of us replaceable, even though we see ourselves as unadulterated, always ourselves. Once again, this knowledge of the paths of the elements shall therefore become the source of a transformation of our relationship with these substances, as we encounter them in our daily lives. Each speck of dust may then appear sacred, part of ourselves, a realization then inviting us to delve into this life-changing truth of the earth, leaving behind the futility of the world, to bring this revelation into it, unlimitedly sharing it with all our brethren.

The following journey will be rather brief. It will avoid pointless arguments, scientific controversies, and vacuous speculations, to favor a poetic recounting, using a language close to the senses, apter to induce a personal experience, bringing one closer to the magnificent realm that we can feel with our skin, keeping us close to its surface. It is not meant to simply be read to acquire a form of knowledge. It should rather become the starting point of a regular practice, a frequent reassessment of one' s relationship with the earth. Each day, our consciousness should be turned toward our planet, this compact

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mass of matter carried through the wheels of the skies since time immemorial. One should want to persistently re-explore these tales, durably letting them shape his life and become part of it. May the following pages become seeds for personal growth, one that should be followed by a willingness to offer to others what we have received, nurturing its extension, favoring its refinement, until all would forget themselves while treading these paths, leaving only the earth in their stead.

Part I

The Story of the Earth Under Us

Our relationship with the earth is primarily one that is linked with our *presence*, the fact that we experience it as a continuous unfolding. We, just like our planet, and the entirety of what is encompassed by the heavens, are caught in the river of time, flowing outside of our control, carrying us in a single direction, regardless of our feelings, and without the need for our consent. We advance hand in hand with all the matter around us. This planet is the vehicle transporting us through the way of the skies, toward an unfathomable destination. Our fates appear to be bound, until we perhaps one day find a suitable replacement, but the consideration of an inscrutable future, although enticing, may quickly end up being vain voyages of a fertile imagination, having no bearing upon the reality of our existence. Our capacity to envision what lies beyond the frontiers of our personal experience is nonetheless one of the most wondrous and unique properties distinguishing our species from the other branches of the tree of life. Our gaze may indeed transcend our presence, our being here and now, to take a glance in the opposite direction toward which the flow of time carries us. Peering beyond the narrow horizon of our presence, we may discover hidden truths about our origin, uncovering past events whose consequences reverberate loudly into the present, overlooked and ignored by most, as their significance can only be revealed through the story of their emergence. The past still echoes in our ears, right now, but we need to know about the source of these tremors passing through time to understand their nature. We, minuscule shoots sprouting out of a branch of the tree of life, were shaped by these distant reverberations of the past. We embody them in the present day and carry them toward the future. To know ourselves thus implies a familiarity with the story of our surroundings and of our substance. This will be the subject of the first part of this work.

Furthermore, the story of the earth is tightly intertwined with the story of life. We may presumptuously consider ourselves as mere inhabitants of this planet, creatures reigning supreme over its surface and over the other beings sharing this spherical abode with us, but this would signal a cecity to an essential facet of our nature. Life appears to stand against death, the vast ground whereto the deceased return once the flame of life departs from them, but the demarcation between the two realms is not as clear-cut as it may appear. Life is but a peculiar manifestation of earthly matter. The essence of the living is not fundamentally different from that of what is dead. The clouds above our heads and the rocks under our feet share the same

essence with us. We only differ from them by a curious arrangement of our earthly substance, one that displays a particular complexity and refinement. We embody a fantastically sophisticated arrangement of elements that just happens to exhibit the seemingly miraculous ability to reproduce itself, to evolve according to the passing of time, and to interact with the world surrounding it. Despite the marvelous peculiarities causing life to stand out from the rest of the creation, from death itself, we should nonetheless not lose sight of the fact that we remain mere aggregates of earthly matter, remarkably assembled, bewitched by a mysterious phenomenon, but still mere earth, like the rest of our planet.

As we also are parts of the earth itself, the story of the planet therefore also represents our own, and this is not only because we are made of the same substance, but also because the formation and the transformations of the earth have deeply affected the evolution of the tree of life. Each milestone, each major event in the long story of this planet, has left a mark upon life, one that may still be observed in our own bodies, as it has been recorded in the book of life that is stored at the core of each one of our cells and that broadly defines the development of each individual being, the legacy of our forebears, up to the very first seed of life.¹ But they also left deep traces on the earth itself. Its crust, in particular, is the book of the earth, a diligent record of its history, written with an ink made of minerals and metals, with a wide palette of colors and shapes. We are the first branch of life endowed with the ability to decipher the language of this book of the earth, and we only did so relatively recently.² A considerable amount of work has nonetheless been performed since then, and prodigious efforts have been made by learned men, so that most of its mysteries have now been unveiled. The great story of our planet can now be recounted with a satisfying degree of certainty, allowing us to become acquainted with this facet of the source of our being, and better understand our own nature.

¹That is, the DNA molecule, the genetic code.

²Geology as a scientific discipline began in the 17th century, with the coining of this term by Ulisse Aldrovandi, and the formalization of the principles of stratigraphy by Nicolas Steno. Among the most important milestones of this discipline, we find the first explanation for the origin of earthquakes in 1760 by John Michell, the first use of radioactivity to date rocks by Arthur Holmes in 1911, or the uncovering of the origin of the moon, the result of an impact with a planet named Theia by Reginald Daly in 1946. For more information concerning the history of this discipline, see: O' Hara, Kieran D. *A Brief History of Geology*. Cambridge University Press, 2018.

The Story of the Earth Under Us

Each time we tread upon the face of the earth, we explore a page of its great story. Encountering a cliff, what we see is one of its chapters shown to us as layers upon layers of sediments, patiently accumulated across the ages, deformed by the tremors of the crust, cut out by its unhurried movements. We live among the ruins of the events experienced by the earth, and thus, by reading this long story, in books or in the ground itself, we are offered the chance of being able to read the language of the earth, to see what each stone, each mountain, or each pit can tell us. These ruins are nonetheless not only visible under our feet. Raising our eyes up toward the heavens, beholding the pale complexion of the moon, bearing the visible scars of numerous violent encounters with asteroids, we observe another chapter of this grand planetary adventure, as it was born out of the earth itself, during a cataclysmic event whose traces have now been deciphered. Our beloved planet nonetheless still keeps a few of its secrets. We may have begun to explore the depths of space, but the core of the earth remains out of the reach of our more sophisticated tools. The future may reveal new chapters of this story, or revise some of them, but what we already know is already more than sufficient to guide us toward a deeper appreciation of our indestructible bond with this planet. May we seize this chance of growing more intimate with our surroundings and see our earthly nature more clearly, letting this newfound awareness leave a deep imprint upon our heart, leaving its trace upon the foreground of our mind, until the day when the scaffolding of our flesh will inevitably crumble, when the mysterious fire of life will depart from us, and all that will remain of us will once again circulate between the earth, life, and the air.

The Story of the Earth Under Us

Chapter 1

The Accretion of the Earth

The greatest accomplishments always begin with a small step, a seemingly insignificant action setting in motion a long chain reaction giving birth to something bearing so little resemblance to what triggered it that any mention of such parentage would only be a source of incredulity. Our home planet may be considered to be such an accomplishment, so astounding in its elegance, composed of such a wide palette of dazzling landscapes striking awe and wonder in the heart of the men beholding them, that these admirers of nature would seldom imagine that it comes as the result of a mere coalescence of random elements violently scattered throughout the emptiness of the cosmos, seemingly by a mere twist of fate transformed into what we are now given the chance to observe, to hear, to touch, to smell, and to taste during our numbered days on this place upon which the name of “earth” has been bestowed. Our beloved home is nonetheless no more than a vast aggregation of stardust, sublime in its refinement but incredibly crude in its composition, a visible demonstration of what a simple set of laws of nature can build with a lump of matter, mingling order and chaos, to turn the primordial impulse of the creation into a work of art, of which we are part. To appreciate this incredible journey of the planet we inhabit, one must first consider the source of the clay wherewith it was shaped, before paying close attention to these agile hands. Then may the astounding nature of what surrounds us shine brightly in our eyes.

It would seem perfectly appropriate to inaugurate this voyage

into the essence of the earth with a sentence uttered by one of the first philosophers whose work has reached us, Heraclitus, who perspicaciously noticed that: “From all things one, and from one all things,”¹ sometimes rephrased as “out of all things comes a unity, and out of a unity all things.” Seemingly obvious, these words nevertheless cut right into the heart of the question of the origin and destiny of the earth. This brief and simple sentence perfectly embodies the course of the universe, and in such a tension between the parts and the whole, the one and the many, may we see our planet’s first and final instants. The oneness of all that is that reigned at the beginning of the long story of our universe, a story that may possibly only be a single step in an inscrutable, deeper past, was brutally turned into a manifold array of particles randomly scattered through various force fields and several dimensions, as space itself was precipitously unfolded and stretched to an inconceivable extent. This array appears to be a fluctuation of the very ground of existence, energy manifesting itself through space and time, leading to uneven distributions of matter, like a gargantuan fog soon shaped into nebulous masses under the influence of one of the major forces ruling our universe: gravity. The unicity of the primordial energy burst into a diversity of particles, which in turn patiently coalesced, each pushed toward others with a strength proportional to their masses, with the imposing gathering the lightweight to inflate itself. When sufficiently massive, pushing its matter so forcefully toward its core that it overcomes the forces binding the particles together,² it ignites and shines throughout the darkness of space, and thus is a star born, patiently consuming its essence and fabricating increasingly heavier elements, working like an alchemist creating substances out of others, changing the simplest arrangements of elementary particles into more complex ones. Not yet the sun, this star is rather its parent, as our star will be formed out of its smoldering ashes, just like the earth itself. Eon after eon, this toil of the parent of the sun continued, until all the hydrogen out of which most of it was formed was transmuted into the heaviest element that can be produced by the work of gravity alone: iron.³ This time marks the old age of the

¹Original Greek: “ἐκ πάντων ἓν καὶ ἐξ ἑνὸς πάντα.” From: Patrick, George Thomas White. *The fragments of the work of Heraclitus of Ephesus on nature*. N. Murray, 1889. Page 128.

²That is, when gravity overcomes the so-called “strong force” binding neutrons and protons together.

³Stellar nucleosynthesis, the creation of new elements from nuclear fusion, begins with the fusion of hydrogen atoms, the simplest atoms, into helium. It then continues according to the order given in the periodic table of elements,

The Accretion of the Earth

radiant sphere, an end that will soon sow the seeds of a new beginning. Having exhausted its immense strength, but still attempting to reignite its fire, it then explodes in a magnificent display of incandescent projectiles, colorful clouds, and trails of a wide palette of elements embellishing the skies. The rupture of the fiery sphere allowed it to create through its death what it could not during its life: it forged elements heavier than iron. In this epic firework, the rarest substances of our world were born: silver, gold, mercury, or lead! The metals forming many of the pillars of our world find their origin in such a cosmic cataclysm. Thus, from the oneness of a star, the great variety of the elements out of which the earth was shaped came to be.

The mother star of our sun therefore scattered its own remains so that its progeny may arise from its ashes, and by its death, it successfully transcended the boundaries fixed to it by the very scaffolding of the cosmos itself, giving rise to a flurry of new substances, without which we would not be here today. Our luminous parent disappeared in a trail of smoke and dust, fine grains of matter dispersed in one of the arms of our galaxy, leaving this gift enclosed in darkness, with only the faint glitter of its distant cousins gently touching this sacred whirlwind. The pulse of the cosmos nonetheless continued to beat, and the gigantic explosion of the star was but one of them, paving the way for another that will soon follow.

The cloud of primordial matter pervading the universe, mostly composed of a precursor to water, hydro-gen (“source-of-water” in Greek), and helium, the featherlight gas used to suspend balloons in the air, heavier than this substance, is enriched by the constellation of elements forged in its last instants by the extinct star. The past star has given birth to innumerable specks floating through the emptiness of space, but the almighty and versatile hands guiding the course of all that is are already working their magic. Electricity, the same force that causes our hair to rise in contact with wool, also causes these specks of stardust to stick together, forming small grains blending different elements. These grains are then brought

ordered by increasing number of protons and neutrons, with gaps due to the instability of some of these elements, such as Lithium, Beryllium, or Boron. Helium thus produces carbon, then neon, oxygen, silicon, and finally iron, the 26th element of the table and the heaviest one that can be produced in the normal activity of a star. Heavier elements are mostly produced by supernovae, or cosmic catastrophes such as collisions between massive celestial bodies. See: Kutner, Marc L. *Astronomy: A Physical Perspective*. 2nd ed., Cambridge University Press, 2003. Page 179.

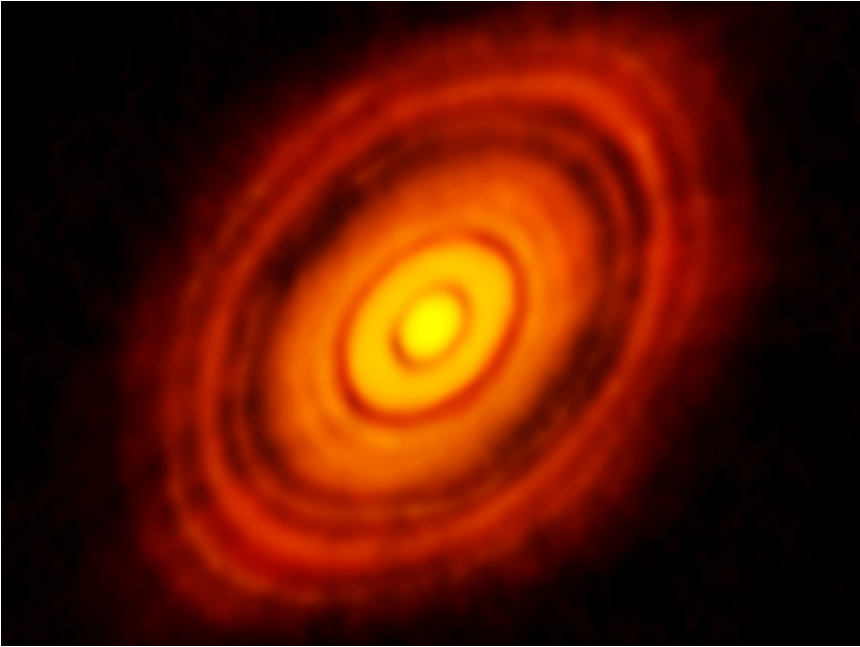


Figure 1.1: *Image showing the protoplanetary disc surrounding the young star HL Tauri (From the European Southern Observatory, using the ALMA telescope).*

together by the force bringing all things endowed with mass to coalesce, gravity. One grain after another, little pebbles take shape, mainly composed of iron and silicate minerals, with traces of all the others that are now naturally found in the crust of our planet.⁴

The counterbalancing movement to the explosion of the ancient star continues, with many particles constituting a multitude of pebbles randomly colliding in the vast Tenebrae of space. The encounters began as soft contacts ending with a weak bond uniting them together, but as the size of the aggregates slowly increases with the passing of time and the work of the invisible hands of the cosmos, so does the violence of these encounters, causing friction, stirring up the fabric of these lumps of matter and causing it to release heat, radiated in the cold and somber depths surrounding these events. This dance of the particles, this meeting of the pebbles, nonetheless occurs in different locations. The bulk of the gas and dust is united at a center point, but in the distant periphery of this cosmic axis, smaller congregations appear, sufficiently distant not to be absorbed by the great assembly at the center, but close enough to it so as to slowly orbit around it, as a whole. The seed of our sun was thus planted, together with the embryos of all the planets that will soon circle the nascent star.

The smallest perturbation of the most insignificant specks of this stellar dust may have catastrophically altered the course of the history of our planet. Even further than this, the most infinitesimally small fluctuation of the emptiness of space itself during the unfolding of the heavens may have caused our beloved home to simply never have been, forever wiping us all from the great story of the creation. But as said by Nietzsche, “One must have chaos within himself to give birth to a dancing star.”⁵ Chaos itself pointed out the location where the sun would be kindled, and where the earth would be placed, just distant enough for life to appear. Without the arbitrary unevenness of the distribution of matter, this array of swirling clouds may not have been. Chaos may be seen as our father, but in this

⁴The composition of the crust of the earth is as follows: Oxygen 45.5%; Silicon 27.2%; Aluminium 8.3%; Iron 6.2%; Calcium 4.7%; Magnesium 2.8%; Others 5.3%. These percentages are taken from: Chang, Raymond. *Chemistry*. 9th ed., McGraw-Hill, 2007. Page 49.

⁵Translation by the author. Original German: “Man muss noch Chaos in sich haben, um einen tanzenden Stern gebären zu können.” From: Nietzsche, Friedrich. *Nietzsche's Werke Bd. 4. Morgenröthe*. Leipzig Kröner, 1917. Page 19.

case, our mother would be the Cosmos⁶ (“order”), as the unseen order balancing the other force. The first stirred up the primordial impulse. It mingled the ingredients, but the latter now begins to show its power that until now remained largely unseen. Cosmos is as fundamental as chaos. Order is the frame in which this chaos is expressed, even though at times the content of this frame may be strong enough to deform it. The universe is defined by the interplay of order and chaos. It thrives through their perpetual interaction, with chaos representing the bustling energy that gave birth to all things, and order the underlying structure through which all these things were given their shape, were imparted the uniqueness of their nature, such as whether they became matter, light, space, or time, all fruits of a singular essence.

As the randomly scattered bits of matter began to coalesce around the center point hosting the most massive aggregate, they followed the invisible furrow traced by the cosmos itself to guide their course, which is far from random. What may have initially been a trivial impulse imparted by a celestial catastrophe, such as the magnificent explosion of the parent of the sun, upon the stardust and primordial clouds floating in the emptiness of space, set the nebulous mass into a spinning motion as it began to be concentrated in its center. Following the furrows of the laws of nature, the paths that all things are forced to take, these growing bits of matter all began to follow one another, running on a circular trajectory, joining a single course patiently taking them to a common destination, a common destiny: to become part of the whole that is shaped at the center of this cosmic circle. As the grains of matter remain modest in dimension and loosely bound together, the spinning motion to which they all submit causes them to naturally form a disk, pressed vertically by each revolution, perpendicular to the axis of rotation, but at the center, as more and more compact masses crash into one another, like lumps of clay assembled by a potter, a sphere is formed, only slightly affected by the spin’s pressure, making it only slightly ovoid. The same phenomenon occurs in each distant mass of particles circling this central concentration, forming the growing embryos of the planets now adorning our sky.

Order and chaos can be seen at different scales in this grand commotion at the origin of our existence. Chaos holds sway over the smallest scale, with seemingly random fluctuations of the vac-

⁶The word “cosmos” comes from the Greek word “κόσμος” [kósmos], meaning “order.”

uum of space,⁷ the very scaffolding of nature, continuing to gently stir up all particles but letting an order appear among them, with atoms bonding to form groupings, following the paths traced by the fundamental laws reigning in this universe, and these groups later arranged according to secondary or tertiary structures. Chaos nonetheless reappears, as the colossal number of orderly constructed bits of matter causes them to erratically bump into one another. The resulting commotion causes the most minute bits of matter to radiate some of their strength as heat, while others naturally emit an even more powerful form of radiation, like the one later harnessed by man to produce monumental explosions or power turbines allowing his world to turn.⁸ The combination of both soon melts the pieces of rocks and metals haphazardly gathered by the elusive force attracting matter to matter. Out of chaos, order then once again appears, as the multitude of pebbles, boulders, and asteroids is slowly thrown into a cosmic crucible, changing shape and being given a red hue, a visible sign of the considerable disorder reigning among its tiniest parts.

New celestial bodies are thus patiently shaped, as their substance becomes more malleable as their heat increases. They resemble spheres more and more, exhibiting the perfection of what does not differentiate the three dimensions of the space into which they are thrown, embracing symmetry. The strength of their spin nonetheless creates a rift between dimensions, favoring a longitudinal alignment, perpendicular to the axis of rotation, but it remains negligible in front of the impressive mass of matter assembled there. As the orbiting matter continues to get closer to these spheres, they naturally accelerate, since the impulse seizing them remains relatively constant while their circular course becomes shorter and shorter. This, in turn, further stirs up the chaos reigning among the molecules

⁷Quantum vacuum fluctuations are a consequence of Heisenberg's uncertainty principle. It states that some physical properties cannot be absolutely determined, and that a level of uncertainty is part of the very fabric of the universe. An absolute vacuum with a total absence of energy would violate this principle, and it thus appears that the energy level of a vacuum varies constantly and possesses a non-zero value, seemingly violating the second fundamental law of nature: the conservation of energy, even though these fluctuations seem to cancel themselves almost instantaneously, rendering such violation, if it really occurs, extremely short-lived. For the first publication of this principle, see: Heisenberg, Werner. "Über den anschaulichen Inhalt der quantentheoretischen Kinematik und Mechanik." *Zeitschrift für Physik*, vol. 43, no. 3-4, 1927. Pages 172-198.)

⁸That is, nuclear fission.

forming these celestial bodies, making them more malleable, letting gravity easily smooth them like gargantuan orbs of molten glass.

Thus were the sun and the earth born, in darkness at first, and then with only a faint glow. Out of the innumerable things begotten by the explosion of a single star, unity slowly reappears, but this is not a mere return of the old. It is rather an event marking the emergence of something new. As said by Whitehead: "The many become one, and are increased by one."⁹ What is formed by the collections of heavenly rocks and pieces of metals is more than their mere sum. A home has been created, built with rocks and metals. A celestial hearth has also been prepared, mainly made of the lightest elements, hydrogen and helium, and it is now simply waiting for its kindling.

The giant, incandescent bodies continue their round dances. The largest one circles around the center of the galaxy, while the others revolve around it, continuing to grow as countless additional pieces are thrown into these crucibles of the sky. As they briefly disturb the perfection of the spheres when they crash onto their surface, they are soon welcomed by the whole, becoming indistinguishable parts of it. The central mass of matter, the giant orb around which the planets now orbit nonetheless soon differentiates itself from the others, not only by its stature but also by its nature.

As the invisible hands of the cosmos relentlessly labor to preserve the symmetry of the great orb of gases and dust swirling around itself, fed from the depths of space, compressing this mass of matter with more force as it grows in mass, something that does not occur among the planets then occurs. Due to its gigantic nature, the attraction of all parts of the orb to the core of the sphere they form becomes so violent as to crush matter upon itself, overcoming the bonds uniting particles, breaking the structures formed by the frame of nature itself. The quiet order of the faintly glowing sphere is disturbed, and it suddenly breaks down with intense bursts of light, as the lightest element is transmuted into a heavier one, releasing a formidable amount of energy, stirring up a prodigious luminous tide illuminating the face of all the planets in its orbit, even reaching the depths of the galaxy.¹⁰ The force locked into matter during the primordial expansion is now unlocked and let loose, allowed to

⁹From: Whitehead, Alfred North. *Process and Reality: An Essay in Cosmology*. Macmillan Company, 1929. Page 32.

¹⁰This phenomenon is known as "nuclear fusion."

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roam free at the fastest possible speed, running to the confines of the creation. The sun has now been ignited! The celestial hearth has been lit! It now brightly shines, not like embers, as do the nascent planets, but rather like the most intense furnace, and it will one day cause those beholding its countenance to lower their gaze so as not to be blinded by its incomparable splendor.

The birth of the sun marks the rebirth of its ancestor, the star whose death produced all the matter out of which it was formed. Our star is born out of the ashes of its parents, and one day its own remains may engender another generation, a new, radiant celestial body. Out of the chaos of the minuscule, the greatest order once again arises. As said by Heraclitus: “This cosmos, which is the same for all, has not been made by any god or man, but it always has been, is, and will be an ever-living fire, kindling itself by regular measures and going out by regular measures.”¹¹ The cycle continues, with chaos and cosmos dancing with one another, birthing entire new worlds by their all too natural union. The pulse of the creation unceasingly beats, with stars lit and exploding, worlds built and destroyed, driven by the first impulse that reverberates through time and space, incarnated as matter, trapping this impulse as small particles, not letting it go until these particles are themselves broken, crushed, and the impulse is once again allowed to escape and be propagated. There is no chaos without cosmos, and no cosmos without chaos. Both are two sides of the same coin, endlessly rotating, stirring up the aether in its vicinity. Our world, and thus we ourselves, are born out of this grand, chaotic wave channeled by the order of things.

The earth, our home, came to be because of the irresistible attraction between grains of matter, and, through the same agency, the daystar was ignited, just like any other of the countless stars scintillating in the night sky. The accretion of the planet from stellar dust and primordial clouds is nonetheless only the beginning of our world, the foundation, made with rock and iron, upon which a new order will emerge, one that will preserve the freedom of chaos in its midst.

¹¹Translation by the author. Original Greek: “κόσμον τόνδε, τὸν αὐτὸν ἀπάντων, οὔτε τις θεῶν οὔτε ἀνθρώπων ἐποίησεν, ἀλλ’ ἦν ἀεὶ καὶ ἔστιν καὶ ἔσται πῦρ αἰεὶ ζῶον, ἀπτόμενον μέτρα καὶ ἀποσβεννύμενον μέτρα.” From: Patrick, George Thomas White. *The fragments of the work of Heraclitus of Ephesus on nature*. N. Murray, 1889. Page 125 (Fragment 30).

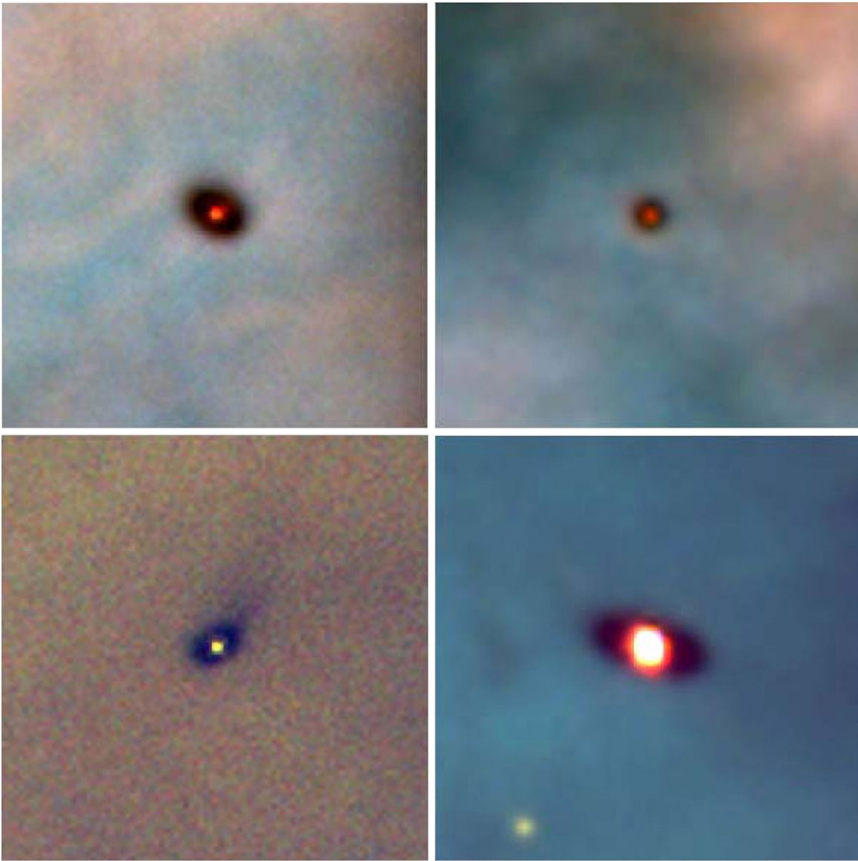


Figure 1.2: *Four protoplanetary disks around young stars in the Orion Nebula* (From NASA, taken with the Hubble Space Telescope)

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In a distant past, an ancient star, having reached old age and exhausted its strength, whose origin is wrapped in mystery, suddenly burst into a splendid, colorful display, a cosmic firework, scattering innumerable shards around the darkness of a universe without any eyes to behold this wondrous spectacle, or so we presume. Once its work of alchemy was complete, as it turned the simple into the complex, and refined the primordial elements into new creations, thereby creating a wide palette of substances out of a handful of primary ingredients, it then generously distributed its products, throwing them to the galactic winds, like a farmer sowing his seeds, knowing this gift would at some point become the source of a new world. These minuscule pieces, the dislocated, incandescent corpse of a dead star, featherlight but blazing specks floating in the cold emptiness, isolated, defenseless, then soon fell under the far-reaching influence of an elusive force, gathering matter against matter, pushing the light toward the heavy, rubbing them one against the other, setting them ablaze, until some of them formed the magnificently ordained sphere now found under our feet.

The arcane force that gathered the ashes of the star, mother to the sun and the earth, is the same that now jealously keeps us close to the face of our planet, preventing us from reaching the clouds and the celestial bodies adorning the heavenly vault. This force predates the earth itself, and it is responsible for its accretion. Letting ourselves fall onto the ground, we not only experience the embrace of our home, but we also feel the hidden hand of the universe, a tangible manifestation of the most fundamental order of things, the curvature of space itself, ineluctably driving us toward what is heaviest. This is what turned stardust into the earth, shaping it into a sphere. Falling down, being pulled down by the planet itself, we now recognize that the earth is also under the influence of this mysterious property of matter. We, like her, are subjugated by it, but we may acknowledge the fact that we are also endowed with its power, as we both attract all the things in our vicinity as well, even though in our case, this power is almost negligible due to our modest stature. Observing our bodies, we may also notice how we differ from the earth. Unlike the earth, our flesh valiantly resists the power of the force shaping the planets and the stars. It has broken the perfect symmetry of the sphere, the shape adopted by the things submitting unconditionally to this force. Our limbs are there to oppose it, to allow us to stand erect upon the smooth face of the earth, proclaiming our uniqueness, demonstrating our courageous resistance, our obstinate refusal to be

enslaved by it. Feeling our limbs, watching our peers oppose the pull that shaped the planet by merely rising up, we may value the strength of our flesh, which stands up against the shaper of all the greatest celestial bodies.

Taken in the monumental whirlwind stirred up by the explosive death of a star, that was the mother of our sun, its ashes were also rubbed together by the round dance led by the strange force of attraction of matter to matter. This intimate contact between the multitude of pieces of these stellar remains caused them to grow warmer, burning for each other in a loving embrace of rocks and metals. This radiating heat, this chaos of the minuscule, grew together with the nascent planet itself, until it became a giant orb of magma, molten iron allied with blazing minerals, a flurry of substances flowing like a river of liquid embers, a celestial cauldron where a heavy brew is continuously mixed, composed of ingredients forged by the genitor of the sun itself. Observing the rocks forming the ground around us, what we see and touch are the remains of this glorious recipe, what was concocted in this spherical crucible. Granite, feldspar, or basalt are the remnants of this ancient sea of magma, having cooled enough to turn into these stones. They were formed soon after the explosion of the star whence their substance came, the resulting fire providing the heat necessary for their forging, rather than in the terrestrial cauldron, insufficiently hot for such a task. These rocks may feel cold to the touch of our fingers wherein our iron-infused blood flows, but if they are not colder than ice, it is not only because of the envoys of the sun striking them by day, but also because of the persistence of the commotion of the accretion of our planet, the original warmth of the earth that can still be felt to this day, and without which we may cease to exist.

The tepidness of the ground is the distant echo of the waves stirred up by the rubbing of the ancient pieces of compacted stardust that coalesced to create what is now our home, the voice of the chaos that reigned during its first days, even before the sun itself was kindled into the brilliant luminary it is today. Caught between the warmth of the blazing iron core of the earth and the fieriness of the daystar far above us, we have the chance to enjoy a climate that is almost perfect for life to thrive, and we may be thankful for this incredibly fortunate order that arose out of the chaos following the explosion of the sun's mother star. This heat, encapsulated inside this stardust, has been offered to us by the same force that shaped all the spherical bodies of matter hung upon the celestial

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vault, and the one upon which we stand. Feeling the need to express our gratitude for this priceless gift, we may raise up our hands, or just as well lower them down, for it surrounds us on all sides, and we even bear it within ourselves, as all the things endowed with heaviness, as far as the ripples of space can reach them, now bow toward us, as we bow toward them all. Letting this fact penetrate the innermost parts of our soul, we may focus our attention on the experience of this remarkable and yet cryptic force pervading us all, and to which we owe our precious existence.

Strolling through the marvels of our world, the highly ordered avenues bordered with angular towers of stone and iron, lined with mirror-like transparent sheets made of baked silica, all forming the bulk of the earth's substance, we may reflect on the source of this improbable order. This fine layer coating the planet we call our world, this intricate maze containing the most astounding treasures of tangible refinement and intellectual reflection, ultimately is the product of a chaotic whirlwind of stardust, a cosmic tempest of epic proportions, with the same minerals and metals forming vast clouds collapsing upon one another, in a fiery vortex whose destination was a single point in the depths of space, itself revolving around the center point of our galaxy. The most perfect order came to be from the seed of the most complete chaos, matter pulverized into the finest powder, without structure, and seemingly without an architect. Looking at the result, what we see is the work of the very scaffolding of the cosmos. The primordial impulse that caused the emergence of all matter out of the tiniest folds of space itself simply followed the way traced for it, the channels of the edge of the skies, and thus particles turned into substances, and then these formed large aggregates, until this impulse flowed into a new furrow of the cosmos, becoming the mystifying phenomenon we call life, before we played our part in this long path of nature, building up the cosmos out of chaos. We thus are the primordial impulse, the drumbeat of the universe, and what now stands in front of our dazzled eyes is only a milestone, following the one built up by life itself, but certainly preceding others. We may be proud of what has been accomplished since the accretion of our planet, the first step of the ordering of a form of chaos, itself the product of the collapse of a previous order. But we shall nonetheless see ourselves in the eye of the truth of nature, as only a mere manifestation of the same impulse animating all that is, from the grandest stars to the most minute speck of dust.

Chapter 2

The Solidification of The Earth' s Crust

Clouds of stardust pressed into a blazing orb of matter, the earth is a blazing but malleable clay shaped by the unseen hands of the order of the universe. The planet is given its form, but it has yet to become the foundation of a world. The innumerable specks of dust chaotically swirling in the emptiness of space have now been united, made into a whole emerging from these countless particles. The reign of chaos recedes in this part of space, but it still holds sway over various aspects of this newborn planet. The friction linked with the shaping of this voluminous lump of matter has set its substance ablaze, melting the various aggregates of elements composing it, and thus this agitation expressed at the scale of atoms causes the appearance of vast currents, rivers of liquid metals and minerals swirling even more unpredictably as the stellar dust previously did in space. These enormous torrents, stirred up by the commotion of its most minuscule parts, freely flow in every direction. They rise toward the surface or plunge toward the center of the sphere. They go around in a circle on its surface, letting their heat be dissipated in the cold Tenebrae of the cosmos, or remain close to the center, receiving the heat of other similar fluxes. Out of this new expression of chaos, a new order nonetheless slowly appears.

The same mysterious force that gathered the stellar dust and transformed it into this ball of liquid fire continues to shape the destiny of this little lump of matter suspended in the immensity of the creation. With mankind still largely ignoring the finest details of this

quality possessed by all elements, we simply define the “mass” of a piece of matter as the extent to which it responds to the irresistible call of all other things also having a “heaviness.” So intuitively known since our youth, as we witness the pull of the earth taking all except the lightest things to the ground, we easily fail to realize that the nature of this property we call “mass” remains one of the most fundamental mysteries of nature. But observing our surroundings, we can see how substances naturally seem to order themselves according to this quality, in liquids especially. Seeing droplets of oil floating on a puddle of water, we know that it means that the first substance is lighter than the latter. Likewise, inside the terrestrial cauldron, a great number of elements are therefore patiently separated from one another as the currents continue to go on their course, on their endless, spherical circuits. At first, all are randomly mixed together, but groupings then begin to appear. Metals quickly sink toward the center, with iron soon forming the bulk of the innermost core of the planet, allied with some nickel and other trace elements. Crushed so energetically, this core becomes solid, despite its prodigious heat. Surrounding this solid sphere of metal, the liquid outer core is mostly composed of the same two metals, only subject to less pressure, allowing it to remain fluid, circling the solid orb. These currents of molten metals lead to the formation of a new large-scale impulse, a force differing from the commotion of the elements or the downward pull gathering all things endowed with mass: a magnetic field enveloping the entire planet, and this field’ s ability to deflect the solar winds and cosmic radiations would later prove to be crucial for the emergence of life. The earth is nonetheless not a mere iron sphere. Lighter elements, mostly minerals assembled according to various compositions, then slowly form another layer of our then young planet, the “mantle,” clothing the metallic core with a robe of molten rocks.

The mantle itself is the theater of a continuous reordering of matter. Most constituents of this layer are not isolated but rather embedded in different minerals, whose composition determines their weight, and thus their place in the terrestrial ranking of the totality of its substance. Silicate minerals, rich in heavier atoms like iron and magnesium, remain at the bottom, while silica-rich rocks like granite and basalt float on the surface. The great differentiation, the vast reordering of the substance of the earth into a gradient corresponding to the response of its ingredients to the omnipresent force gathering all the things we call “matter” together, is now largely complete.

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This nonetheless does not imply that the early earth became peaceful and quiet. It indeed is at this point still bewitched by the vitality of youth. It bustles with movements, whose source comes both from within and from the outside, from the earth itself as well as from the sky.

Molten sphere of incandescence, the young earth is teeming with activity. It first boils from the inside, leading to frequent explosions, with lighter substances, gases in particular, violently ejected from the planet, banished to its outskirts, condemned to simply envelop it. Magma is sprayed away from the surface through circular holes, which puncture the surface before fading away, furthering the refining of the layers of the planet, with gases forming its last layers, with the same ranking occurring also among these ethereal substances floating above the surface.

A second source also interacts with the blazing vestment of the planet: the heavens themselves, as they send legions upon legions of asteroids crashing upon its red-hot face. The stellar bodies orbiting around the sun were then far more numerous than now. The young solar system was filled with rage and energy, and thus was the earth heavily bombarded by bodies of various sizes and compositions, further reinvigorating the play of the ranking of the substance of the earth, with new additions continuously offered by the sky itself. Like an industrious laborer, the earth thus sorted each one of these gifts from above, melting them and then dispatching their different components according to their rank in the play of "gravity," the game of "heaviness," where the strong pushes its way to the core, leaving the lightweight on the outside.

The interplay of chaos and order is nonetheless still very much at work, right now, playing a crucial role in the development of the planet. Its substance is now largely ordered according to the ranks of the substances composing it, but it remains a place where chaos is let in, insufflating "life" into this great mass of metals and rocks. The perfection of its spherical face, the result of the uniformity of the force of attraction of all matter allied with the fluidity of its fiery body, is continuously disturbed by the chaos from inside and outside, from the earth and the sky. But order nonetheless slowly but surely gains power, as the vitality of youth soon gives place to the quietude of maturity.

As the earth shows its radiant face to its neighbors, its incandescence slowly wanes. The red-hot orb, offering the impulse animating

it in the form of light and warmth, spread throughout the cold darkness of space, soon begins to weaken. Its soft glow, which already was almost insignificant in comparison to the brightness of the star around which it revolves, is now reduced to naught. The rocks composed of lighter elements, like granite or basalt, lose their luster as they grow cold, their heat carried away by the skies, and the liquid face of the earth turns into a solid crust coating the entirety of the planet.

Magma slowly crystallizes, with different minerals each doing so at its own pace, creating a constellation of rocks with unique structures, colors, or textures. This is when the earth becomes more than a blazing sphere in space, and turns into a ground, a foundation necessary in order for something to be built upon it. A form of order is strengthened on the surface, as its solidity renders the landscape quieter, motionless, even though the pressure of the outbursts from above or below is still very much present at this moment in the history of the planet. This newfound order is contrasted by the transformation of the surface, becoming rugose, craggy. Gravity alone is indeed no longer sufficiently strong to level it, and it is now incapable of filling canyons and toppling mountains. The solidification of the crust is an important event. It traces a line separating the stable realm of the earth from the ethereal one of the sky. This line is nonetheless subject to a permanent tension, from above and below, as it is still frequently broken by eruptions and downfalls, showing that the seeds of chaos remain planted in any form of order. This rocky sheet is the white page upon which the story of life will be written, the stage upon which the greatest play will be performed.

Entire eons will pass until man' s forefathers crawl out of the ocean to explore this rocky crust and begin to write their history upon it, but the time of the solidification of the first crust enveloping our planet represents the moment when the earth itself begins to inscribe its own story, not on top of it, as man later will, but rather inside it. The crust itself will, from now on, record some of the major events of its existence, something that was impossible when it was a vast ocean of magma. Layers will form a timeline, and rocks will be the ink with which this history will be written. Like timepieces, minerals will reveal the time when they were crystallized, and their composition will tell of their surroundings. It will take a considerable number of years before anyone will be able to decipher these signs left in the rock, the plentiful and long tales of the crust, but they will remain there, and even the various catastrophes afflicting this



Figure 2.1: *Solidification of lava on a volcano in Indonesia.*

medium will not be enough to erase their meaning. On the contrary, with every impact of a celestial body scarring the face of the earth or with every earthquake or eruption disfiguring the crust, new pages are written, and nothing vanishes. Each scar is a sign left on this spherical, craggy page, waiting to be read by a curious and capable observer of the lower realm of nature, someone able to unearth the memory of the planet.

The crystallization of the ground is also an event that echoes in the present. It traced the line of our horizon, constraining the things found above the surface of the earth. This limitation of the movement of the creatures living above this horizon nonetheless offers them stability, fostering a form of freedom of movement, as this line exerts a force, a resistance, expressed toward another. The second line of force manifesting itself on those roaming above the ground is the force that shaped the planet itself. The “plumb line” is perpendicular to the one traced by the ground. It goes through one’ s body and to the very center of the earth, the heavy core mostly made of solid iron that irresistibly attracts all things within its reach, keeping them close, attempting to absorb them so that they would become one with the body of this celestial sphere. Gravity brings down, restraining the living, and the rigid crust further limits them, but the conjunction of these forces allows them to ap-

propriate the spherical surface and move more easily upon it than in the depths of space. Without any stable structure upon which they may lean, without support, the seemingly absolute freedom enjoyed by something thrown upon the air or emptiness itself would imply considerable challenges, and make their existence more difficult than on the ground. Each creature living at the intersections of these two lines of force is offered the face of the earth as its territory, given the chance to make it its home, caught between the impenetrable rocky crust and the ethereal air followed by the vast emptiness of space. Only man is aware of the nature of this gift, but he, like many other living things, has nonetheless learned to emancipate himself from the ground, exploring the third dimension that for a long time remained inaccessible to life, except for those swimming in water. Using wings or jet engines, they have now conquered this new dimension, having appropriated the air and the depths of the skies, something that nonetheless would not have been possible without the support of the tepid crust of the earth, as a foundation of the world of the living.

As the scattered ashes of a star that illuminated the distant past were carefully gathered by the invisible hands of the cosmos and turned into a spinning, spherical ember, it offered its warmth to the cold depths of space, patiently gaining in stability what it lost in shine, becoming the rocky crust whereon we now stand. Vigorously striking it with our heel, or lying down upon it, our arms wide open as if we embraced this giant sphere, we may begin to notice what a precious gift it represents to us. We can feel ourselves being pulled by this gigantic orb floating in the vastness of the skies. This may be seen as space itself being inclined by the considerable weight of the iron core at the center of this sphere and of the gargantuan mass of flowing magma furiously running in circles deep under the quietude of the cold and rigid crust, unconditionally supporting us. This mass attracts us, just as we attract it and all other material things. Lines of force may be perceived, joining us with the heart of the planet, and we may relate this incredible and yet common experience to the work of attraction of the celestial bodies above us. The pale satellite bringing the sun' s brilliance into the darkness of the night remains attached to our planet through a similar bond, just as the earth itself is bound to the grandeur of the daystar, around which our world revolves and on which it relies. Attempting to feel the lines of force binding us to the massive body of matter under our feet, we may imagine what would befall us if the earth were now as it was at

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the time of its birth, a spherical ocean of molten metals and minerals. If we were to ineluctably sink into the boiling abyss, we would be completely dissolved, becoming one with it, and this would mark the end of our being. Life as a whole owes its existence to the hardness of the ground beneath our feet. Having scattered its warmth in the sky, like seeds of light generously sown into an infinitely large field, it lost both its glow and its fluid nature. The heavy metals sank to the core, and the incandescent sphere naturally ordered its substance according to the mass of its constituents, leaving the surface with the lightest rocks, which are still among the hardest materials of our daily environment, such as granite. The basis of this world of ours, the spherical slab of rock forming the outer layer of our planet, supports all that we create. It is its stability and uncompromising rigidity that make it so precious to us, and thus, placing one of our hands upon it, experiencing its nature directly with our touch, we may appreciate the role it played and will continue to play for the whole of the tree of life.

The basis of our world appears as completely flat to our eyes, unless we ascend to the loftiest peak and see a slight curvature of the horizon, a sign of its true, spherical nature. Our mind nonetheless knows this truth, even though our senses cannot perceive it. This immense, spherical surface is closed upon itself, without borders. There is no edge of the world, no chasm into which we would fall, out of the earth. If this continuous surface is closed upon itself, it is because it is wide open toward the vastness of the skies. It invites us to turn our gaze upward, to wean ourselves off the blazing blood of the earth, to gorge ourselves upon the fresh milk of our galaxy, flowing all across the firmament. Let us appreciate this duality between the closed nature and the openness of the solid crust of our planet, seeing how it orients our world, away from the earth, either turning it skyward or toward the horizon, this great expanse upon which we may freely live and create. Extending our arms toward the heavenly dome, we may let ourselves be moved by this openness, the infinite possibilities it offers, recognizing that the source of this constellation of potentialities is the closed, compact nature of this petrous ground that has borne our presence since the day we were born.

The ground that we intimately know nonetheless only represents the most superficial layer of our planet. When we flee from the smothering omnipresence of life and take refuge in the serenity of deserts of stone, where even the ruins of life are scarce, we are given

a clear vision of the crust of the earth, too often covered with soil, ashes of our forefathers. This skin of hard stone is made of the lightest matter found under our feet. We may picture how the primordial mélange of stardust included all sorts of elements, blended together, mixed by the hands of the universe, and how these were soon organized, ranked according to the intensity wherewith they curve space itself, inclining it so that it would attract what surrounds it. Seizing an object made of iron, caressing its cold, smooth surface, we come into contact with the heart of the earth, for it constitutes both the majority of its substance and also its core, still feverish due to the extreme agitation of its essence, letting its warmth reach the crust, inconspicuously imparting some of its heat to it and thereby fostering the growth of the tree of life. Comparing the heaviness of this material to that of a stone of similar proportions, we see that the contrast is clear, and their rank becomes manifest. Lighter than stone are we, and thus we naturally sprouted out of the earth, occupying our rightful place. We can picture our place within the gradient going from the air, where what is lighter than life floats and is left on the outskirts of the planet, and increasingly massive layers of minerals beneath our feet, up to the rivers of molten iron and other metals running around the solid core, of similar composition. Between the ethereal gases forming the air we breathe, and the rocky earth supporting our steps and our world, we now stand, alone able to consider our own position. The beauty of this fine layer wrapped around this glorious orb sheltering us, balancing lightness and heaviness, playing with the elements found above and below, exalts the meticulous work performed by the hidden fingers masterfully organizing the cosmos.

The blazing core of the earth obstinately remains out of our reach, but it offers us precious signs of its presence, and these can be directly observed if one knows where to direct his eyes. Taking a compass, looking at the way it consistently points toward the north, no matter where we move it, we witness the disturbance stirred up by the underground rivers of molten iron circling the core of the earth. We spend our lives inside this force field, and yet we have remained unaware of its existence for so long. But among the creatures sharing this rocky surface with us, many are able to perceive it with their senses, and employ it to navigate across vast distances, when sight is not enough to find one' s way. Many birds, sea turtles, salmon, bats, butterflies, insects, and even rodents surpass us in their attention to the deepest signs of our planet. Seeing these animals swimming in

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the seas, flying through the air, or running upon the ground, we may wonder at the way they see our common home, with this peculiar sensitivity to the omnipresent signs of the agitation of the rivers of iron running through the deep. Humbling ourselves in front of their skills, let us briefly follow their steps during their migration or their navigation, knowing that we thereby let ourselves also be guided by the earth itself. The earth does more than support life by offering it stable ground. It also guides the course of many, and we may be thankful for this invaluable assistance.

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Chapter 3

The Formation of the Atmosphere

Having let a portion of its inner rage flee to the darkest confines of the sky, the blazing substance of our planet saw its incandescent blood covering the orb it formed rigidify, becoming the ground supporting our world. When a cloud of stellar dust was shaped into this sphere, the ocean of magma was not its outermost layer. An immense mist made of the lightest and most abundant elements of the creation, the bulk of the body of young stars, then enveloped the immature celestial body, as does the air we now breathe. At this point, the earth had yet to rank its substance according to the weight of its numerous constituents. It was still a uniform ball of magma swirling chaotically, and thus, the force field produced by the currents of molten iron running around the core had yet to be deployed. What would later become an invisible shield guarding the earth and its inhabitants from the most violent outbursts of the daystar had yet to be hammered and installed all around the rocky orb we call home, and thus when solar tempests raged in the highest heavens, hurling myriads of the fieriest particles onto the light cloak clothing the planet, it was swiftly ripped to shreds, its fibers scattered in the emptiness of the cosmos.¹ The earth was stripped of its first cloak soon after its birth, but no one was there to endure the enmity of the sky, the realm uncontrollably pounding the ocean of lava with the most brilliant light but also showering it with

¹This shield is known as the magnetosphere. For more details concerning the earth's magnetic field, see: Lowrie, William. *Fundamentals of Geophysics*. 2nd ed., Cambridge University Press, 2007. N.p. (Chapter 11).

innumerable projectiles crossing its path as it circled around the sun.

Once the ranking of the terrestrial substance was sufficiently complete, the invisible shield then began to defend the earth from the sun. It deflected the most dangerous attacks from the star, nonetheless letting part of its radiance flood the land and seas facing its countenance. The major layers of the planet were already demarcated, but this work of titans was still ongoing, and so it remains, even now. The rocky crust was already far from being a monolithic, impermeable coating of the earth. The persistent bustling of the torrents of magma in the mantle unceasingly put pressure upon this crust, breaking, piercing it, or causing large sections of it to sink back into the blazing, liquid inferno, melting and absorbing it back. This movement frequently caused various substances of the depths to come closer to the surface, and the lesser pressure experienced near the outer layer induced changes in some of them, like transitions from a liquid to a gaseous state. Lighter in volume than the molten rocks around them, these gaseous masses were therefore promptly banished to the surface, pushed through cracks or holes in the crust, sprouting energetically out of the ground. Various gases were thus produced by the commotion reigning within the mantle and the outer core, and while their featherlike nature precluded them from remaining inside the great sea of fire, they were sufficiently heavy to be captured, kept close to the surface of the earth, rather than be released into the emptiness of space. The earth thus began to breathe out, letting what it exhaled form a new layer enveloping it, but unlike the first cloak of the planet, this one was protected from the heavenly assaults by the invisible force field born out of the currents of molten iron running around the core.

Different was the air when the second ethereal cloak was laid upon the round shoulder of the earth, but its composition, while toxic to most branches of the tree of life as it now stands upon our planet, was a key factor in the subsequent burgeoning of this glorious tree. It was indeed mostly composed of some of the same gases as those exhaled by our lungs, carbon dioxide (CO₂) and water vapor, in addition to what is now the main component of our atmosphere: nitrogen, a poorly reactive substance that thus slowly became the main presence in the air of the present day, whereas others waned more and more with the passing of each eon, due to reactions with other substances. Some other substances, now largely absent from the air we breathe, were nonetheless already present, and a few of them, noxious to many forms of life, formed the first building

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blocks of this marvelous chain reaction whereof we are parts, such as methane (CH_4) and ammonia (NH_3), as these molecules were struck by lightning or subject to other forces of nature, assembling them into longer chains of atoms that would, one day, light the very first spark of life.² Spewed by the wounds of the earth, sulfur dioxide (SO_2) was also present in non-negligible quantities, triggering the formation of sulfuric acid, later raining down on the surface and weathering the rocks, dispersing the minerals they contained.

The new cloak of the planet grew denser and denser as the years flew by, and due to the strong propensity of its components to absorb the brilliance of the sun, its warmth was increasingly being captured, preventing the diffusion into space of the warmth of the earth.³ A gray haze enshrouded the rocky, spherical wasteland that is now our home. The age of fire gave way to an age of mist, a mist that bore the precursors of life. We indeed often think of ourselves as arising out of the earth, and as most of our flesh is made of the transparent fluid now covering it, we would not be mistaken, but the backbone of life, the carbon found at the heart of almost every part of our bodies, was then suspended in the air. The essence of the entire tree of life was already present, as a grayish wind blowing over a rocky wasteland, struck by thunderous clouds shattering bonds between atoms and fostering the weaving of new ones.

The breathing of the earth and the appearance of the haze enfolding it mark the emergence of a new contrast, between the solid and the ethereal, the ground and the air, the earth and the sky. Clouds began to hover above the uninhabited planet, silently advancing, following the contours of this sphere, compelled to remain close to it by their heaviness, as insignificant as it may be. As noticed by an ancient Greek philosopher, “all is flux,”⁴ nothing remains still, and the air may be seen as a reminder of this fact, continuously and conspicuously displayed across the firmament, night and day, winter or summer, for all ages. Would that imply that the air is an

²The famous Miller-Urey experiment, conducted in 1953, simulated the conditions of the early earth to demonstrate that some of the building blocks of life, such as amino acids, could be formed from compounds found in the early atmosphere using electrical sparks, mimicking the effect of lightning. See: Miller, Stanley L. “A Production of Amino Acids Under Possible Primitive Earth Conditions.” *Science*, vol. 117, no. 3046, 1953. Pages 528–529.

³This is known as the “greenhouse effect.”

⁴Original Greek: “*πάντα ῥεῖ*.” This sentence is often attributed to Heraclitus, but it is not found in the extant fragments of this author. It is probably a paraphrase, as it still well represents his thought.

embodiment of chaos, whereas the earth would be an incarnation of order? This idea has its merits. Out of the chaotic tempest of star-dust, the earth and its solid ground patiently emerged, and, in turn, as if honoring its origin and rediscovering the roots of its existence, the earth then gave birth to a new realm, having more in common with this primordial nature. Chaos and order engender one another, in succession, one out of the other, showing their interdependency, their interlaced nature. The simple and yet profound words of the Greek philosophers should nonetheless remain present in front of our eyes. All is flux, and not just what appears to be. The cosmic storm that gave birth to the earth may also be seen as having never ended. The planet itself is part of it, with the rivers of magma at its heart equally flowing, enthralled by chaos itself, even though a certain order might appear in it. The blowing of the winds is just the continuation of the same gigantic turbulence that began with the first movement of the cosmos, and the distinctions between the whole and the parts, the earth and the sky, the ground and the air, are thus arbitrary lines delineated by our creative minds.

Man's consciousness is grounded in his presence, his being here and now, observing the flow of time at a certain pace, linked with his capacity to act upon the world around him, and the number of days allotted to him. Outside of his constrained horizon, these distinctions are as foggy as the air enshrouding the young planet. The earth is also in flux, just as the air, only on a different timescale, and the observation of this flux may be deceitful. To our naive eyes, the earth appears as permanent, unchanging, a pillar standing in the flow of a river, withstanding all the attacks of the heavens and life. It appears as a realm that was there long before our world came to be, and that will survive when our creations ineluctably collapse. In contrast, the sky seems to be impermanent, inconstant, something impossible to rely upon, refusing to support the building of anything upon it. And yet, paradoxically, the earth is young in front of the heavens. Chaos is more ancient than order. The celestial vault predates the ground. We are merely being deceived by the rapidity or slowness of their movements, the young ground moving only on the scale of eons, whereas the old sky's commotion is swift, with the winds and the clouds running toward the horizon, continuously shaped by chaos itself, right under our eyes. Earth and sky, ground and air, thus share an identical nature, as fields where chaos and order play with one another, perpetuating the tempest out of which new things emerge, among which are life and man himself.

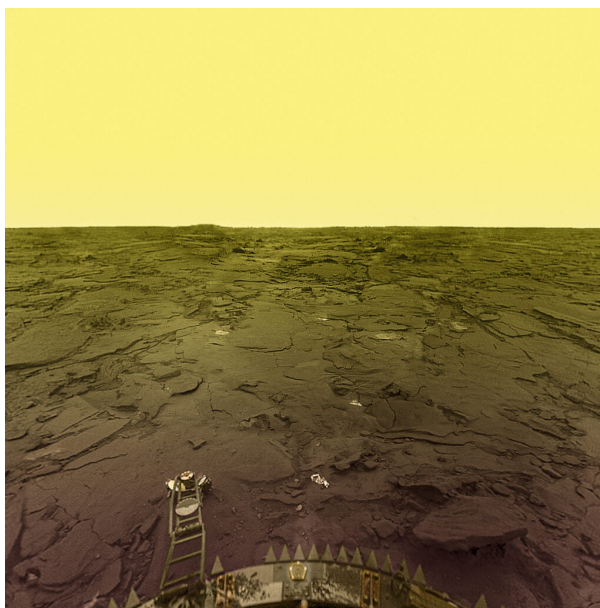


Figure 3.1: *The atmosphere on Venus.* The atmosphere on Earth would have been roughly similar during its formation (Image taken by the Venera-14 lander).

The difference between the solid and the ethereal nonetheless depends on more than a mere whim of man. These concepts bear a degree of arbitrariness within themselves, but for a human being, the frontier between the two is clear. He can breathe one and not the other, walk on one and not the other, without any ambiguity. If the atmosphere were to be deprived of what has been exhaled by the planet, we would not be here. The layering of our home is a prelude to the birth of life, and without the crucial contributions of each one of these layers, from the core and the iron flux creating the shield against the rage of the sun to the solid crust supporting our roots and our seas, up to the highest layers of the air, our beautiful planet would in all likelihood be as barren as the other celestial bodies endlessly circling around the daystar. All is flux indeed, but this flux has formed an almost perfect alliance with the most elegant order to allow the conditions prerequisite to the appearance of life to be met, something that may perhaps be unique in the immensity of the cosmos. We stand like tightrope walkers on the edge of a remarkably lofty tower of possibilities and improbable coincidences. We are the product of an astonishing conjunction of the chaotic fluxes of the universe, an unbelievably complex order built upon absolute chaos

itself. The heavenly currents breathed out of the earth are but one piece of a large puzzle, drawing the tree of life itself, and who knows what wonder will later emerge out from this seemingly eternal flow, when life itself may be superseded by something even more unlikely.

Walking or sitting, standing or lying down, we are now kept close to the surface of our planet. We are forcefully held down by its weight, bending space itself, irresistibly attracting us to the furnace at its core, and only the rigidity and cool of its crust allow us not to be engulfed in its blazing, turbulent depths. The inferno under our feet is nonetheless also a source of our existence. It breathes since its birth, exhaling fumes and vapor that represent the bulk of the coat of air clothing the earth, even though the substance we draw out of the heavens with our lungs, absolutely essential to our life, had yet to appear in significant quantity there. Lighter than rocks and metals, gases are banished from the ground, chased away to the heights, organizing themselves according to their weight. Invisible and odorless, most of these fluids exhaled by the planet are easily overlooked by the inattentive inhabitants of our world. And yet, we are all in permanent contact with this transparent layer of air, this fluid coating our world, more than with our closest friends or our most beloved companions. So inconspicuous is its presence that it cannot be felt unless either we or the air itself actively manifests a desire for an encounter. We may initiate such an event simply by vigorously waving our hands. We may thereby begin to feel the gentle touch of the air caressing our skin, softer than the lightest silk, more delicate than the most affectionate lover. It eludes the grasp of each one of our senses, always with us but never ours, remaining free and yet always captive to the overbearing presence and heaviness of the planet.

Encounters between the air and the living may nonetheless also be initiated by the ethereal body floating over the earth. Forgoing the protection of the lower realm, departing from the seclusion of our stone walls and glass sheets separating us from the vast expanse of fluid wrapped around this giant globe lost in space, it may then come to meet us, getting further acquainted with us, and make us aware of its omnipresent nature. This matter floating in the sky, the deepest breath of the earth, blows through the alleys of our world. It shakes the flowers of the meadows and carries their seeds to their mates, allowing new ones to embellish the creation. It dances

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with the falling leaves and offers man the strength of its impulse by turning the sails of windmills. Feeling the wind upon our faces, enveloping our bodies, we experience the exhalation of the planet, one of the last layers established by the ranking of all earthly matter according to the weight of its elements. We, like the planet itself, now exhale water vapor and what will become the scaffolding of the plants that shall soon elevate themselves, from earth to sky, the carbon representing the backbone of the living, that we trade for what we need from the air to breathe and perdure in the world. The carbon within each one of our cells, in each molecule forming our body, once came out of one of the numerous mouths of the earth, such as volcanoes, underwater vents, or out of its wounds, faults and cracks, through which the lightest substances fled the dark blaze of the depths to embrace the luminous coolness of the heights, a phenomenon continuing at this very moment. Feeling the air slipping through our fingers, let us be aware of its earthly origin, and of the key role it plays in our brief existence.

Considering our own nature, we may then notice that we also occupy a designated place in the ranks of all earthly matter. Our very substance has also been exhaled or excreted by the ground beneath our feet, and despite all our wit and the grandeur of our civilization, our world largely remains in the place attributed to it by this ranking. We cannot plunge into the rocky soil. Every incursion into it is merely a displacement of earth to create passages through which the air can slip, extending its territory in one place and reducing it in another. Likewise, every conquest of the air by man is always temporary, demanding a great amount of effort to oppose the natural order of the planet, bringing us back to the surface where we belong, with incredible force. Taking a glance at our world, we can see that we are caught between earth and sky, not by a mere whim of fate or as the result of our labor, but simply because our flesh is lighter than iron and rock, and it is heavier than the air above our heads. We may take a moment to ponder our place in this great ordering of the entire body of the earth, from the solid, iron core, up to the last traces of matter circling high above the surface, so far as to even touch the moon itself.

We nonetheless do not need to feel the winds to witness the power of the air, the breath of the earth. Opening our mouth, letting the aether pass through our throat as it animates our vocal cords, reverberating on our palate and the walls of our nasal passages as it joins back the immense expanse of the heavens, we can

hear our voice being carried by this fluid. We have triggered an invisible but audible wave propagating throughout the sky, as a vibration of the minute grains of matter floating around the globe, letting information fly to the ears of men and other creatures. Had this air not been exhaled from the depths of the ground, the lower heavens would have almost no substance. We would be deaf and dumb, powerless, and the melodious tunes of birds and musicians would not resound throughout the avenues of our world. Paying close attention to the medley of voices and sounds surrounding us now, let us picture the earthly origin of this gift, being thankful for the power it graciously offers us.

Furthermore, the celestial aether also supports all the creatures that have made the lower skies their home. They fly thanks to its slight but nonetheless constant resistance to their push, bringing life far above the surface, allowing the winged ones to elegantly emancipate themselves from the omnipresent pull of the planet, for a time at least. The highest layers of the ethereal vestment of the earth nonetheless do more than merely support the flying creatures. It primarily protects the middle realm caught between earth and sky, acting as a shield, permanently raised above our oblivious heads, defending life against the formidable attacks of the skies. The tremendous radiance of the daystar, for example, vivifies us when received in moderation, but it would scald our skin in the absence of the different lines of defense set up by the earth. The first shield, raised by the iron core of the earth, deflects the most harmful radiation directed toward the surface. The air represents a second line of defense, of a different nature. It can absorb the most energetic and thus potentially dangerous rays coming from different stars, and it can also literally burn down most of the objects attempting to intrude into the territory occupied by life. When asteroids enter the upper sky, they indeed become meteors, leaving blazing trails adorning the heavens, marking their rapid disappearance, as they are melted and dispersed by the friction with the substance of the air, unless large enough to escape such a fate. Raising our eyes above the horizon, we behold this vast shield protecting us from the threats of the deep cosmos. Let us feel this line of defense of our world, which may have more than once saved us from extinction, knowing that it is the earth itself that set it up high above us. This mass of aether, clouds chaotically formed and scattered, is the most transient of all things, and yet also the strongest and most permanent wall standing between our world and what threatens its existence. We shall

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thus be grateful for its constant presence. The next time we see a shooting star, let us be mindful of the existence of this shield, whose protection we then witness with our naked eyes.

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Chapter 4

The Birth of the Moon

As the great ordering of the substance of the earth was almost accomplished, the planet formed of a gradient of layers, extending to the sky itself. It even included the transparent, fluid envelope of the hardened sphere, organized according to the mass of its elements. A form of peace then prevailed between earth and sky. Such peace implies stability, a prerequisite for the emergence of new things, but also stagnation, preventing the rise of others. Life had yet to appear in this tranquil, barren wasteland. No eyes were there to contemplate the hazy sunsets, and no hands nor claws were there to leave their mark upon the rocky ground. Order ruled the earth, but what good is an order that does not bear any fruit? When order holds sway over a world, chaos nonetheless ineluctably pushes against this domination, sooner or later, and what may initially appear as the breaking of peace may at a later point turn out to be a blessing in disguise.

As said by Heraclitus: “War is the father of all, and king of all.”¹ War sometimes needs to interrupt an era of peace, so that the whole can transcend the barriers hindering its evolution. War may be a form of reordering, breaking parts of a world so that a new one can be built upon its ruins, one that may exhibit a higher form of order, impossible without it. Once the layering of the earth and the lower heavens was largely complete, the planet was nonetheless seized by uncontrollable movements, a wobbling causing it to balance

¹Translation by the author. Original Greek: “Πόλεμος πάντων μὲν πατήρ ἐστι, πάντων δὲ βασιλεύς.” From: Patrick, George Thomas White. *The fragments of the work of Heraclitus of Ephesus on nature*. N. Murray, 1889. Page 127.

itself irregularly, with a tilt greatly varying according to the forces it was subject to, such as the pull of distant but massive planets, like Jupiter, or various celestial bodies adorning the heavens. The barren wasteland then experienced extreme variations of climate, with torrid periods randomly alternating with the most frigid ones, an environment poorly suited to the emergence of life. Fortunately, fate placed a stumbling block upon the path of our planet, one that may represent both the most severe catastrophe of its history and a unique opportunity for a new order to emerge, an extraordinary alignment of coincidences that would later prove to be crucial for the kindling of the fire of life.

The earth then had a neighbor, a planet of more modest stature, named Theia,² about half as large, also circling around the sun, rarely feeling the presence of the earth. Probably very similar to it in its composition, having been fashioned from the same sort of mélange of stellar dust, mainly made of metals and minerals, it was almost a sibling. But one fateful day, their path crossed. They collided with such a cataclysmic force that it would change both of them forever. The impact, oblique rather than head-on, was of such an unimaginable violence that it instantly shattered the crust of the entire earth, turning it once again into a blazing mass of magma. So brutal was this encounter that it even briefly broke its spherical shape, sending immense trails of molten rock and metal far above the fluid layers coating the planet. The two masses became one, their blazing essence mingled, taking and giving with the other. Magma rained upon the surface of the now incandescent ocean formed by our planet for centuries or millennia, and it would take a considerable number of years for the crust to once again cool down and be hardened by the work of time. This cataclysm is nonetheless not a mere reset, a return to the time of the great ranking of the substance of the earth. Indeed, the impact has left a conspicuous trace, not upon the earth, but in the sky itself. Ejected by the collision, in all likelihood combining the substance of the two celestial bodies, a fiery mass slowly coalesced high above the surface of what would become the ground of our world, spinning around our planet, sufficiently close to feel the attraction of its core, but distant enough not to be absorbed by it. As it patiently offering its warmth to the earth and the dark depths of space, the complexion of this newborn satellite

²Theia, from the Greek Θεία [theía] meaning “divine,” is the mother of the moon in Greek mythology. This is why this name was chosen to designate the other planet whose collision with the earth led to the creation of the moon.

The Birth of the Moon

grew paler, soon ceasing to shine, but rather simply reflecting the brilliance of our star, and it remains hung in our sky, bearing the name of “moon.”

Whether a celestial act of war, an impromptu battle of heavenly bodies, or a passionate union, the event may be seen under different lights, but its result is now a tangible monument displayed every day in front of our eyes. One of the most important consequences of this cosmic encounter is nonetheless seldom pondered by those bathed in the pale glow of this satellite. Unceasingly dancing together, the courses of the earth and moon are correlated with one another. They are inextricably bound, and this dance profoundly affected and continues to affect the movements of our planet. The chronic wobbling that seized it until then slowly fades away, as the earth's rotation is from now on constrained by the pull of its satellite, calming its agitation, soothing its tremors, bringing order to the chaos at play in its midst. Like a spinning top, whose rotation allows it to stand and resist the downward pull, the earth is guided by the moon, given a relatively unchanging tilt. This would later prove to be an invaluable gift, as this stability and this precise tilt led to the creation of the seasons, the yearly variations of climate caused by the inclination of the planet toward the sun. Without this catastrophe, the climate would change almost randomly, according to the whims of this orb of rock and metal, and this may have been enough to extinguish the young flame of life or to prevent its kindling. The celestial battle between the earth and its sibling therefore fathered the moon and brought a new form of order by breaking the one that was previously established. Destroying the patient work of ranking the earth's substance, the intruder therefore ultimately causes its perfecting, with more stability and peace than ever before coming as the result of this cataclysm.

The silvery orb, queen of the night, harmoniously paired with the bright king marking the pace of the days, remains in the orbit of the earth, but the violence of its birth nonetheless continues to slowly push it away from it. With no more than a handbreadth with each revolution around the daystar, the gap between the satellite and the body around which it revolves has already grown tenfold since its formation. Inconspicuously at the scale of our lives, it departs from us, taking its independence from this heavy sphere we call home, severing itself from its parent. It thereby also lengthens the days with each passing year, only by a fraction of the blinking of an eye over the entire history of man, but over the course of eons, its effect



Figure 4.1: *An artist's vision of a large-scale collision.*(Woodcut from: Rockwell Kent, *Lunar disintegration*, 1937. *The Prints of Rockwell Kent: Catalogue Raisonné*. Jones, Daniel Burne. Alan Wofsy Fine Arts, 2002: 118. Print.)

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will one day become substantial.³

The moon largely shares with the earth its substance, and it is likewise arrayed into different layers, but the contrast in their appearance is nonetheless striking. On our side, we have a planet teeming with activity when seen with the eyes of the cosmos, sweeping the horizon of time itself. It exhales a deep breath, remaining close to its surface, forming a fluid envelope, continuously in motion, with clouds forming and scattering, eruptions and movements of the crust frequently reshaping the ground, attesting to the vitality of our home, which was crucial to the emergence of life. On the other side, we have a sleeping satellite, charming but barren, beautiful but paralyzed. Its ashy face does not change. It bears the scars of every time it was struck by rocks falling from the sky, and even the footprints of the rare men having trodden its dusty ground have still remained intact, despite numerous revolutions of this duet of celestial bodies around their common star, whereas similar traces on the earth are swiftly erased by the winds, the rains, and the other forces of the sky. The depths of our satellite are still warm,⁴ remembering the commotion of the impact that induced its birth, but its skin is ice-cold, without any trace of activity, no wound out of which its fiery blood would flow, revealing its inner nature. These two worlds stand against one another. They were once one, but have been divided by fate. They are made of the same matter, but it shows itself under two very different lights, with only one of them able to sustain the flame of life.

The peaceful complexion of the sleeping satellite gives us an image of almost perfect order. It circles the celestial vault every day, always showing us the same side of it. Its face bears the scars of numerous encounters with smaller heavenly bodies and these scars are preserved, passing through the ages, as a history book, written in dust. The earth facing it appears radically different, as if it were seized by chaos itself, with its graded hues reflecting the great va-

³Due to the growing distance between the earth and the moon, the day grows longer by 1.7ms each century. See: Stephenson, F. Richard, and L. V. Morrison. "Long-Term Fluctuations in the Earth's Rotation: 700 BC to AD 1990." *Philosophical Transactions of the Royal Society of London*. Series A, vol. 351, no. 1695, 1995. Pages 165-202.

⁴It seems that the structure of the moon is similar to the structure of our planet, with a hot iron core surrounded by a liquid mantle. The crust of the moon is nonetheless proportionally thicker than that of the earth. See: Weber, Renee C., et al. "Seismic Detection of the Lunar Core." *Science*, vol. 331, no. 6015, 2011. Pages 309-312

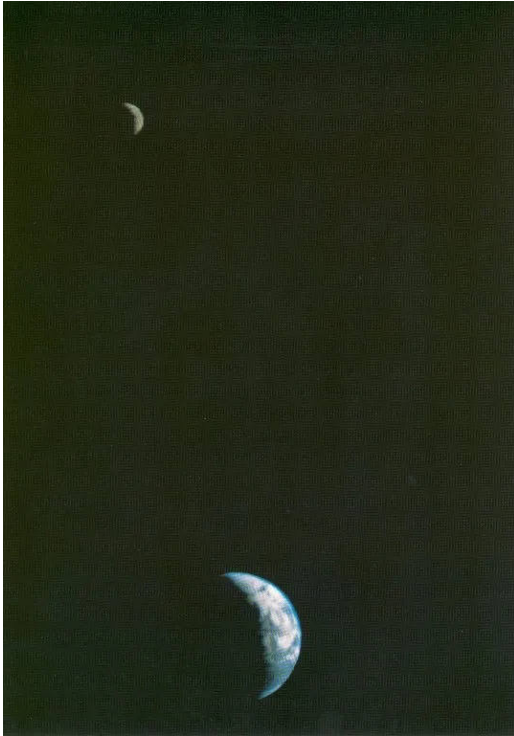


Figure 4.2: *The First Picture of the Earth and the Moon* (NASA).

The Birth of the Moon

riety of things present on its surface, the liquids and the rocks, the living beings and their world. Bustling with movement, our planet nonetheless also may be seen as displaying another form of order, only visible to those able to perceive its astonishingly complex nature, the tremendous amount of conditions necessary for it to exist as it is now. The moon is a sign offered to us, a lifeless pearl passing through the sky, a mirror showing us what we are, what life is in contrast to the countless sterile masses floating in the depths of space, equally bathed in the radiance of giant stars, shaped by the skillful hands of the universe, but whose order is plain, an image of death, lacking the beauty of a world filled with life, possessed by chaos.

Raising our eyes above the frontier separating earth from sky and searching for the most splendid luminary of the night, the pearl of the sky, we may contemplate the delicate glow of this strange, scarred sphere circling through the firmament, once the daystar has retreated under this line encompassing our world. It once set the pace of the months, but now the calculations of men have superseded the rhythm of its dance with sunlight, only leaving vague traces in our calendars. Born out of the smoldering flesh of the earth, the moon remains its only celestial child, one having no memory of its coming into being, but we, mere humans, have succeeded in piercing this secret, and we may commemorate this crucial event in the history of our planet. Long before life crawled out of the oceans, even before the oceans themselves covered the face of the earth, the earth was suddenly struck by another celestial body. Let us imagine the extreme violence of this celestial encounter, with a projectile half its size unexpectedly crashing down on one of its sides, obliquely. The hardened crust, similar to the one upon which we stand now, was instantly returned to the blazing depths, part of it sprayed widely into space. Like two droplets colliding, they mingled their substance, spinning and swirling, until the force of attraction of matter to matter overcame the titanic force of the impact, slowly calming the commotion reigning in this part of the cosmos, once again reshaping the planet. Part of the blended mass was nonetheless already too far gone into space, and it was thus shaped into a second sphere, the moon now dimly shining upon us. It now stands as a seemingly eternal monument to this violent but nonetheless fruitful meeting between celestial bodies, no matter where we are. Entire branches of life were born and extinguished; empires rose and fell,

but the complexion of the moon remains constant, and its course is without surprises, well-understood since the dawn of our history. Knowing that it is a mere barren orb of magma covered in fine dust, rather than some sort of deity, we may nonetheless celebrate its birth and honor its presence, for the role it plays in our lives, and for life as a whole.

More than a mere ashen torch of the night, guiding the creatures venturing after dark, the moon represents one of the foundation stones of our world, one too often overlooked. We perceive the ground under our feet as the basis, the source of stability allowing us to construct our common kingdom above it, but without the cataclysmic collision that engendered the minor luminary, our planet may still be randomly wobbling. This event brought constancy and stability to the spinning of our home planet, giving it a precise tilt and thereby causing the emergence of the seasons. Considering the passing of a year, a complete revolution of the earth around the sun, with its continuous, seamless transition between hot and cold, rain and snow, blossoming and withering, time for harvest and time for sowing, we may appreciate the role played by this catastrophic event in the wondrous changes we witness with each new season that comes. The bucolic forests littered with reddened leaves during the autumn; the long walks in pristine snow squeaking under the pressure of our boots; the smell of the fresh flowers dispensing their enticing perfume to all those touched by the spring breeze, or the torrid caresses of the daystar when we offer our bare skin to be marked by it on a bright summer day, all these moments we owe to the pale orb silently and discreetly passing through the heavenly vault, each day, and we thus may express our gratitude, for the whims of fate, a day of fire and brimstone before we came to be, that led to the appearance of such magnificent contrasts, preserving the seed of chaos, as we can never be sure of what the sky of the morrow will display, but can nonetheless rely on the predictable succession of the seasons, upon which large portions of our world depend, such as the production of our sustenance, out of the earth, following blessings from the heavens.

The echo of the brutal union of the earth and its sibling planet continues to resound throughout the earth. Still dancing together, so long after the event that brought the moon into being, the earth and its satellite are still under the spell of the impulse of this great impact. As it circles the earth each day, we may witness the power of the moon if we venture near the shores of the great ocean. There,



Figure 4.3: *A Meteor Crater.* (Arizona, USA)

we see with our own eyes how the satellite causes the seas to bulge, attracting the entire expanse of water toward itself, causing the water to recede from the coasts, as they follow the pale orb adorning the heavens. Such an elevation of the ocean can nonetheless be witnessed twice a day, as it also occurs on the opposite side of the earth simultaneously, due to the inertia of the waters taken up by the pale satellite.⁵ Observing the ebb and flow of the tides, we behold the reverberating echo of the great collision of two planets, long before there were any eyes to contemplate this wonder. Even though it remains imperceptible, we are likewise the subject of such a far-reaching attraction. The moon pulls us toward itself, attempting to rob us of the arms of the earth, but we, just as well, only with an insignificant force, also pull it toward us. Let us take a moment to reflect upon these invisible bonds between us and this heavenly child of our planet. This event nonetheless also echoes within life itself, more perceptibly, as many of its branches now use the signs of this modest luminary. The spawning of corals is sometimes paced by the unveiling of the moon, as full triggers this event.⁶ The tides also shaped the very nature of many creatures occupying the coasts,

⁵The high tide caused by the presence of the moon directly above it is called the “direct tide,” whereas the one where the satellite is on the other side of the planet is called the “opposite tide.”

⁶An example of the influence of the phases of the moon on life would be the timing of the mass-spawning of corals. For more information, see: Kaniewska, Paulina, et al. “Signaling Cascades and the Importance of Moonlight in Coral Broadcast Mass Spawning.” *eLife*, vol. 4, 2015. N.p.

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exploiting the succession of ebbs and flows to their advantage. All of these ramifications, tying the living with the moon, represent as many reverberations of the event that led to its dolorous birth.

The traces of the dramatic birth of the sleeping satellite are nonetheless more pervasive than meets the eye. They are not only found in the sky. They are not only present in the visible manifestations usually associated with the silvery luminary of the night. Beholding our own body, feeling it resist our touch, the hardness of our bones and the flexibility of our watery flesh, we may be in contact with the remnants of the sibling planet of the earth, its ruins that became one with it during the violent encounter. We may very well bear the ashes of this distant celestial body within ourselves, as it merged its essence with the earth. We therefore may also see ourselves as the fruits of this brutal union, ourselves brothers and sisters of the moon itself. The echo spread within us, and it continues to spread through every one of our actions.

Seeing the delicate glow of our satellite, jewel of our nights, splendor of our vigils, we may then wonder what other surprises will fate place upon the course of our existence. Even armed with the tools of our civilization, our science, we would still be powerless to face another event of such grandiose and terrifying proportions. Life itself may be entirely extinguished by a repetition of such a clash of worlds. Let us thus be thankful for the present instant and for the long existence that has been given to the tree of life, as it may not be eternal. Our days may be counted, and another moon may one day stand close to this one, as a durable monument to our disappearance, and therefore, we shall live the present day as if it were to be the last, cherishing the instants of joy and not holding on to the torments, always embracing the chance offered by the present, our *presence*.

Chapter 5

The Condensation of the Oceans

The earth is still feverish from the traumatic event that led to the sudden birth of the moon, and its face is surrounded by a thick coat of steam laden with a wide palette of substances exhaled from its deepest entrails. It's agitation nonetheless begins to be calmed. Its turmoil is slowly soothed, as it sends torrid waves through the depths of the cosmos, carrying away its excessive heat. The steam enfolding the globe nonetheless only partly arises from the inside of the planet, as what would soon become our home then frequently receives offerings from the inscrutable depths it faces, with gifts of ice, metals, and minerals hurled onto its surface, often brutally scarring it. Promptly melted by the sizzling rocks forming the ground, the ice it receives is vaporized with a loud hissing. It rises in the sky, barely visible, leaving only faint traces in the hazy envelope of the planet. The fiery earth is at war with the icy gifts from the heavens. This phenomenon may resonate with the following words of Empedocles, Greek philosopher of nature and the elements:

The coming together of all things brings one generation into being and destroys it; the other grows up and is scattered as things become divided. And these things never cease continually changing places, at one time all uniting in one through Love, at another each borne in different directions by the repulsion of Strife. Thus, as far as it is their nature to grow into one out of many, and to become many once more when the one is parted

asunder, so far they come into being and their life abides not. But, inasmuch as they never cease changing their places continually, so far they are ever immovable as they go round the circle of existence.¹

Here, the strife of fire and ice results in the defeat of the latter, which retreats to the heights, the bond binding its most minute parts shattered by the intense commotion reigning inside the ground, with its grains of matter frantically agitated, still enthralled by the impulse of the accretion of the planet and the great collision that melted the young crust. Love and strife nonetheless are inextricably bound to each other. Each defeat is an opportunity to be reborn, to become something new, and to accomplish one's destiny.

After having slowly let its glow vanish, the effulgent face of the earth once again turns into a matte, solid ground. What was once a smooth surface becomes a vast, rugose expanse, with crevasses and peaks, mountains and valleys. It becomes an empty vessel, whose geometry defies our intuition, as it is fully convex, but can hold anything endowed with mass, and it now simply waits for a downpour to receive a liquid that would not only change the face of the planet but also its destiny. The agitation imparted onto the steamy vapor covering the earth by its blazing body then slowly wanes. The power of the strife begins to weaken, and this is when love seizes its chance. The minute grains of water suspended in the air can now begin to playfully interact with each other, rather than merely collide and scatter. Affinities are found between them, subtle bonds, not as strong as those binding its components together, the single atom of hydrogen and two atoms of oxygen forming each one of these bits of water, but nonetheless enough to radically affect their behavior as a whole, and their appearance.² Each grain of

¹Translation from: Burnet, John. *Early Greek Philosophy*. Adam and Charles Black. London, 1920. Page 207; Original Greek text: “δοῦη δὲ θνητῶν γένεσις, δοῦη δ’ ἀπόλειψις· τὴν μὲν γὰρ πάντων σύνοδος τίκτει τ’ ὀλέκει τε, ἡ δὲ πάλιν διαφρομένων θρεφθεῖσα διέπτει. καὶ ταῦτ’ ἀλλάσσοντα διαμπερὲς οὐδαμὰ λήγει, ἄλλοτε μὲν Φιλότῃτι συνερχόμεν’ εἰς ἓν ἅπαντα, ἄλλοτε δ’ αὖ διχ’ ἕκαστα φορεύμενα Νείκεος ἔχθει. [οὕτως ἦ μὲν ἓν ἐκ πλεόνων μεμάθηκε φύεσθαι] ἡ δὲ πάλιν διαφόντος ἐνὸς πλεόν’ ἐκτελέθουσι, τῇ μὲν γίνονται τε καὶ οὐ σφισιν ἔμπεδος αἰών· ἦ δὲ διαλλάσσοντα διαμπερὲς οὐδαμὰ λήγει, ταῦτῃ δ’ αἰὲν ἔασιν ἀκίνητοι κατὰ κύκλον.” From: Leonard, William Ellery, editor. *The Fragments of Empedocles*. The Open Court Publishing Company, 1908. Print. Page 20–21 (Fragment 17).

²These subtle forces are the “hydrogen bond” and the “Van der Waals force.” For more details about these forces, see: Atkins, Peter W., and Julio de Paula. *Physical Chemistry*. 8th ed., Oxford University Press, 2006. N.p. (Chapter 14B.2).

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water begins to experience a very slight attraction to the other grains found in its vicinity, an attraction that nonetheless stops and even turns into a repulsion when the two are exceedingly close. They thus delicately dance with one another, this new force never being strong enough to sever the bonds between the constituents of water itself. Little by little, each grain suddenly finds itself surrounded and dancing with an increasingly greater number of partners, as the impulse imparted upon them by the warm body of the earth continues to disappear. Overcoming the strife that caused them to collide and remain isolated, the bits of water are now seized with a form of love, caressing each other gently, staying together, forming a community, a whole, in a manner similar to what is described by these words of Empedocles:

... At one time they are all brought together into one order by Love; at another, they are carried each in different directions by the repulsion of Strife, till they grow once more into one and are wholly subdued. Thus in so far as they are wont to grow into one out of many, and again divided become more than one, so far they come into being and their life is not lasting; but in so far as they never cease changing continually, so far are they evermore, immovable in the circle. ³

The energy of the impulse now calmed by this soft dance, which caused the commotion previously reigning among them, must nonetheless go somewhere, and thus the bits of water release it by transferring this impulse to the air around it, warming it further as it itself grows cold.

When the coalescence reaches a threshold, the whole that it forms is now heavier than the air surrounding it. The unuttered, ancient law commanding the ranking of all earthly matter according to its mass, with the heaviest things offered the closest proximity

³Translation from: Burnet, John. *Early Greek Philosophy*. Adam and Charles Black. London, 1920. Page 210. (Fragment 26) Original Greek (Entire fragment): “ἐν δὲ μέρει κρατέουσι περιπλομένοιο κύκλοιο, καὶ φθίνει εἰς ἄλληλα καὶ αὐξεται ἐν μέρει αἴσης. αὐτὰ γὰρ ἔστιν ταῦτα, δι’ ἀλλήλων δὲ θέοντα γίγνont’ ἀνθρωποὶ τε καὶ ἄλλων ἔνθεα θηρῶν ἄλλοτε μὲν Φιλότῃ συνερχόμεν’ εἰς ἓνα κόσμον, ἄλλοτε δ’ αὖ δίχ’ ἕκαστα φορούμενα Νείκεος ἔχθει, εἰσόκεν ἐν συμφύοντα τὸ πᾶν ὑπένερθε γένηται. οὕτως ἦ μὲν ἐν ἐκ πλεόνων μεμάθηκε φύεσθαι, ἦι δὲ πάλιν διαφύοντος ἐνὸς πλέον’ ἐκτελέθουσιν τῇ μὲν γίγνονταί τε καὶ οὐ σφισιν ἔμπεδος αἰὼν ἦι δὲ διαλλάσσοντα διαμπερὲς οὐδαμὰ λήγει, ταύτῃ δ’ αἰὲν ἔασιν ἀκίνητον κατὰ κύκλον.” From: Leonard, William Ellery, editor. *The Fragments of Empedocles*. The Open Court Publishing Company, 1908. Print. Page 28.

to the center of the planet, continues to rule every part of this little world, even the foggy, steamy heights. Endowed with mass, a droplet of water hung in the highest sky is thus suddenly noticed by the pull of the earth. The great ranking forgets no one, even the most seemingly insignificant droplet. The dancing bits of water therefore begin to fall down toward the core, as a whole, at times supported by the swirling winds, taken back to the heights, but at others brutally pushed down, as if punishing the impudence of this group violating the order painstakingly established, ordering all matter according to its mass. This first drop of the history of the earth is inevitably stopped in its course toward the blazing core, as it strikes the hard skin of the planet, warm, but no longer sizzling, letting the droplet run upon it. This water then hastily searches for the lowest ground, a place that is closest to the destination it is called to reach, the center of the planet. Running until it is stopped by an impenetrable barrier, the droplet faithfully seeks to find its place in the great ranking, and with this journey of the first droplet of water, from the sky to the earth, a new page of the history of the earth begins to be written, as it marks a foundation stone of the great ocean that now covers most of its face.

The earthly, inverted chalice begins to receive the libation from the heavens. One by one, raindrops strike the ground, proclaiming their arrival with a harmonious, soothing pitter-patter, and when they encounter others, the same forces that led to their creation are at work to unite them into a larger whole. When they are already on the lowest point of the earth accessible to them, having found their place in the great ranking of the earthly matter, there are no longer any constraints limiting the size of their coalition, as there were when they condensed high up in the air. Drops then turn into puddles, and puddles into ponds. Ponds turn into lakes, and soon the lakes become seas. The foggy landscape evolves as the translucent cloak of the planet loses its warmth. Out of the thick fog, dark clouds form, carried by the raging winds, and they pour out their heavy burden into the giant vessel waiting to receive it, down below. A mere drizzle then evolved into a deluge, one that may have lasted longer than the time mankind has been standing erect upon the ground. On and on, the sky opened its vaults widely and generously offered its wealth to the earth, patiently accumulated, drop by drop, becoming the treasure of the planet, coating its rugose skin. These riches of the air were nonetheless not limited to the crystalline liquid. Each drop carried its lot of samples of a variety of substances floating in the



Figure 5.1: *A Pool of Water* (From: Sasint / pixabay.com)

steamy atmosphere: Carbon dioxide, what we exhale from our lungs, but also sulfur and other gases that ooze out of the wounds of the earth. This made the great deluge more than a mere offering of clear water caressing the face of the earth, as its load carried another form of strength, another power, the power of attacking and corroding the rocky skin of the planet.

As the corrosive torrents from the sky ran from the rocky promontories of the planet to its deepest chasms, they robbed the ground of some of its riches, swiftly severing the bonds between its tiniest parts, hewing grains of various minerals stored within the crust, and especially one that would give it its taste and become a resource essential for our survival: salt.⁴ Carrying off its booty, the rivers and brooks then amassed this treasure in the coffers of the ocean, waiting for it to be used, along with various other elements. The love between the bits of water, causing them to form this whole, leads it to strive against the ground, carving its face, digging great canyons, patiently, knowing it makes up with perseverance what it lacks in raw force. It thereby already offered a lesson, even though no one

⁴That is, sodium chloride (NaCl), which is most commonly designated as “salt,” even though the term of salt designates a whole class of chemicals. Salt water thus contains different salts, in addition to sodium chloride, such as magnesium chloride (MgCl_2) or calcium sulfate (CaSO_4).

had yet arrived to pay attention to it. In the words of the Chinese philosopher Laozi: “The highest good is like water. Water benefits all things and does not compete. It dwells in places that all disdain, and thus it is close to the Way.”⁵ Thus, for a considerable amount of time, the deluge taught the way of the water to the earth, patiently shaping the vessel containing it, paving the way for the emergence of the most peculiar phenomenon, the kindling of the first spark of life, in this very ocean fallen down from the heavens, with each grain extracted from the rock being an essential piece, a prerequisite for the budding of this splendid tree to which we all belong. Water sowed the seeds of the love and strife animating us, gathering the essence of the sky and the earth in this liquid ocean, sharing aspects of both realms, combining the heaviness of the rock with the fluidity of the air.

Once most of the crust of the earth was covered by the liquid offering of the sky, after countless revolutions of the planet around the daystar, during which the sole ambient noise was the uninterrupted splashing of the torrential rains disturbing the surface of the great sea, silence then resonated in the air. The thick fog that previously wrapped the rocky orb has now dissipated, as the heavens have emptied their storehouses, pouring their reserve of water down below, now occupying a fraction of the space it did in the air, as it is now liquid, concentrated, flowing upon the craggy ground. The sky is clear. The air finally lets the luminous envoys of the sun pass through and reach the ground and the seas, unimpeded. This is the first dawn that shines upon the vast expanse of water, a gift of the sky, and with it, the air is meticulously transformed by the star itself, as its light breaks down certain gases suspended in the air, like methane⁶ or ammonia.⁷ Thundering clouds also contribute to the fabrication of new substances, assembled with lightning and fire, some of which will become essential precursors of life.⁸ Having borne the carbon dioxide dissolved in raindrops to the ground,

⁵Translation by the author. Original Chinese: “上善若水。水善利萬物而不爭，處眾人之所惡，故幾於道。” From: 阿部吉雄，《新釈漢文大系〈7〉老子 莊子上卷》東京：明治書院，1966. Page 23 (Chapter 8).

⁶Methane: CH₄.

⁷Ammonia: NH₃.

⁸The famous Miller-Urey experiment, conducted in 1953, simulated the conditions of the early earth to demonstrate that some of the building blocks of life, such as amino acids, could be formed from compounds found in the early atmosphere using electrical sparks, mimicking the effect of lightning. See: Miller, Stanley L. “A Production of Amino Acids Under Possible Primitive Earth Conditions.” *Science*, vol. 117, no. 3046, 1953. Pages 528–529.

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the deluge thereby also removed a barrier that prevented the escape of the sun's fire reaching the air, as it was captured by it and accumulated. But then, this carbon carried by the rivers and the seas was itself trapped by the rocks under them, reacting with them to form limestone and other carbonate rocks,⁹ thereby leading to a global cooling of the now blue sphere revolving around the gilded star. This great conjunction of events, with various ingredients being assembled with water and in water, and the establishment of a more clement environment, represents the shaping of the cradle of life, which mysteriously appears very soon after this deluge. But this is only the first step, and the earth itself will continue to nurture the growth of this wondrous chain reaction.

Strolling along a coast, our ears attentive to the soft melodies of the tumbling waves, whispering ancient tales of water striving against the earth, unceasingly recounted, we may let our avid eyes feast upon this magnificent, relaxing vision of the blue desert. Have we ever had the opportunity to contemplate the true extent of the seas? Only a few dozen revolutions around the sun have been performed since the first image of this colorful globe appeared in front of man's eyes, and it is now permanently engraved in our minds. In the past, only the bravest seafarers who engaged in the longest, most perilous voyages could experience the fullness of the dominion of the great waters coating the planet, but now, all are equally shown the place of the seas within our world. The cerulean kingdom covering most of the earth is more ancient than us, but it is younger than the ground under our feet. The blazing rivers of magma, now only flowing in its depths, once formed the surface of the earth, and they fiercely opposed the presence of the crystal-clear substance, chasing it to the heights like swirling jets of steam, as its hissing echoed in the heavens, like screams of agony, no matter whether it came from the heart of the planet itself or fell down from the sky. This gigantic mass of water was therefore once hung high up in the air, a thick fog veiling the countenance of the daystar, capturing its radiant envoys, storing its warmth. But this steamy inferno soon lost its breath. Its vigor waned. Chaos receded, and thus bits of water were offered the chance to coalesce into a first drop, now too heavy to remain suspended in the ethereal heights. This drop fell onto the ground, the first of what would become this liquid plain extending to the

⁹Limestone and other carbonate rocks are composed of different forms of calcium carbonate (CaCO_3).

farthest horizon.

Feeling heavy drops raining down from the darkest clouds borne by the air, transparent pearls of the sky splashing against our naked skin, letting their comforting voice resound deep into our ears, and the coldness of their delicate touch be imparted to the warm blood running throughout our flesh, we may realize that in the same manner was the great ocean born. Lifetimes upon lifetimes of torrential downpours, without an instant of interruption —this is how the seas unhurriedly came to be. The sky poured its heart onto the earth, filling it until its reserves were utterly emptied, and observing the rain, we may there see an image of our existence. The steamy atmosphere indeed once formed an indistinguishable whole, out of which innumerable driblets were born, each unique and yet made of the same substance as any other. Falling earthward, guided by the winds and pulled by the core of the planet, such a driblet has no control over its course and inevitably crashes down onto the rock, becoming earth itself. On this rigid, gravelly surface, all the drops nonetheless see themselves once again becoming a whole, united to all others, indistinguishable from them. They appear different, a clear liquid rather than steam, but their essence has never changed, only their relationship with their surroundings, and in this course of the rain, we may see a vivid image of the nature of our existence, a precious lesson of nature. We are also part of this earth, and the water of the great deluge that once begat the oceans now flows within our veins, and constitutes the major part of our flesh.

Gift of the depths, sprouting out of volcanoes, or present of the heights, found in meteorites hurled onto the ground from the confines of space, water is a unique treasure. The ocean is the cradle of life, and without it, none of us would stand here today. Placing droplets of seawater upon rocks facing the blazing radiance of the summer sun, we may witness a reenactment of the elevation of water, as the luminous rays break the subtle bonds uniting its most minute bits and stir up a commotion, causing them to grow apart. When the threshold of agitation is reached, the droplet slowly vanishes, as its expansion causes it to become lighter than the air around it, and it is thus taken away to the cloudy heights. Likewise, if we attentively observe a sufficiently cold piece of metal or glass, we may witness the appearance of new droplets, condensed from the air, as the commotion reigning within it is calmed by the contact with this glacial object, thereby causing bits of water floating in the air to be attracted to each other and become dense enough to be

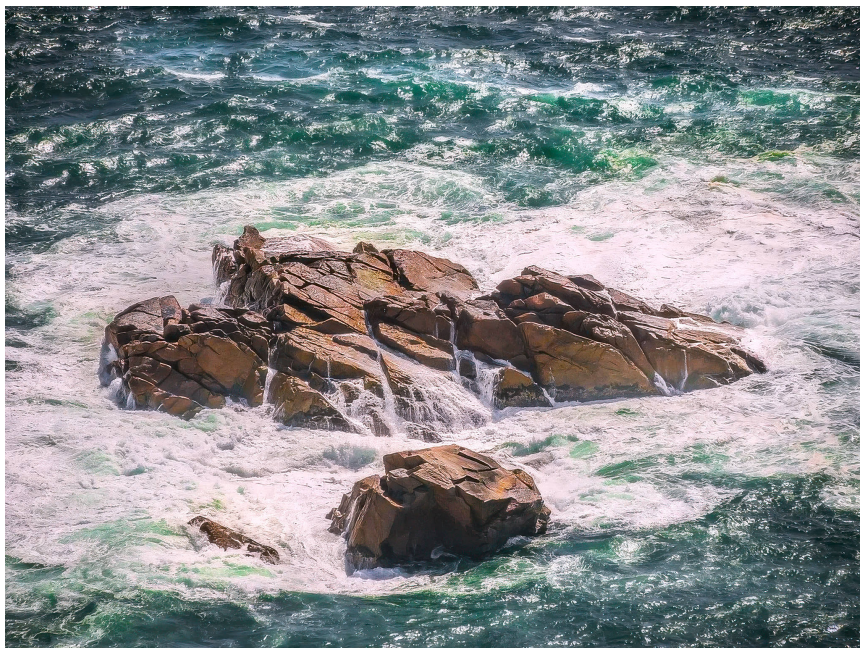


Figure 5.2: *The Ocean*

heavier than the rest of the ethereal realm, thus forcing this water to remain at the surface. Beholding the immensity of the ocean, we may see in it the product of this simple wonder, the ranking of all earthly matter according to its heaviness. This landscape is an almost perfect image of this earthly order, with the contrast between the sea and the air being only the fruit of the sudden overcoming of one force by another, when the attraction between the bits of water surpasses the repulsion between them caused by the commotion we call “heat.”

Leaving our garments upon the shore, letting ourselves be gently carried by the waves of the sea, what we feel is the presence of a gift from the heavens, the result of a deluge that lasted longer than our civilization. Letting it slip through our fingers, experiencing its slight viscosity and its weight, watching the sun and the clouds reflected upon its wobbling surface, we can ponder the nature of the watery cradle of life. The love between grains of water prevailed over the strife that once reigned between them. They now dance with one another instead of colliding and scattering. Between the incandescent depths of the earth and the frigid heights of space, this body of water stands in perfect equilibrium, on a narrow edge between the

immensity of the range of its gaseous nature and the absoluteness of an almost perfect frigidity, a total absence of commotion, implying a solidity. Let us be grateful for the astonishing conjunction of conditions that rendered the miracle of the appearance of life in this ocean possible. Without this deluge, whose corrosive nature allowed the weathering of the ground and the extraction of many ingredients essential to life, then placed into the great earthly cauldron out of which we emerged, the world around us would be nothing but a wasteland, as are the closest neighbors of our blue planet. Let us therefore commemorate this glorious event each time our skin is tingled by a tiny offering from the sky, realizing how ungrateful are those who foolishly complain of this blessing from above. Even if we shiver from the cold or are inconvenienced by the moisture on our garments, we shall rejoice at this occasion to remember one of the most epic events of the story of our planet, one that set the stage for the kindling of the first spark of life. We may no longer be able to inhabit the ocean, but it eternally remains our first home, and our bodies bear the trace of this underwater life. We carry the ocean within our skin.

Chapter 6

The Formation of the Continents

The great mist lay like a garment around the planet, its fabric trapping the sun's luminous gifts, slowly condensing, turning the thick wool into thin silk. It is a fine coating, soft and malleable, reflecting the daystar's bright envoys, sending them to the confines of the sky. The uniform, craggy wasteland forming the ground gave way to a world of contrasts, with the vast, crystalline, and liquid expanse surrounding various islands appearing as the last remnants of the ancient, antediluvian world. The obstinacy of these dry lands not to let themselves be submerged by the great ocean is nonetheless not the result of a mere coincidence. They do not remain above the waters simply because of their original loftiness, like mountaintops that cannot be reached by any deluge, as the fieriness of the mantle was still too great to allow the formation of high mountains, flattening what stood out too much naturally. They rather find themselves there because of their very nature, the composition of their substance, unceasingly being assessed by the earth itself, as part of the permanent ranking of all the matter forming the planet.

The waves and the tides stirred up by the moon are nonetheless not the only forces at play, even if they remain more conspicuous because of their fast pace, easily noticeable by our senses. In the abyssal inferno reigning under the calm crust of the earth, slow but incredibly massive currents continue to flow in a circle around the blazing, iron core. The crust is at all times being scraped from beneath, randomly pushed, causing faults to appear, and causing the

cold, solid layers to be once again immersed in the sea of magma, once again becoming one with it, while other parts are left exposed to the air or the great waters, offering them a chance to let the commotion enthralling them be calmed, letting their surface crystallize and solidify, forming a new crust. This is where the new, watery realm that suddenly conquered the face of the earth played a new, crucial role. Unlike the wounds of the earth exposed to the celestial aether, which allowed ample time for the flaming blood of the earth to turn into solid rock, those exposing the molten rivers of the mantle to the coldness and pervasiveness of the liquid essence of the ocean became the source of new sorts of rocks, a different refining of the substance of the earth.

When a fault appears underwater under the pressure of the mantle's currents, fire encounters water, rapidly cooling the magma. Water penetrates the molten crust, as the lava enters the ocean, and the marriage of both induces the formation of types of rocks lighter than those present before the deluge: granitic rocks. The crust of the ocean is made of heavier, basaltic rocks, laden with heavier elements such as iron, but subject to the extraordinary pressure and cooling power of the ocean, the blood of the earth is refined more than before, with the rocky mantle separated into the light, granitic crust, and the heavier, basaltic one. The ocean thus actively participates in the unceasing ranking of all earthly matter, the great ordering that began soon after the accretion of the planet, and perdures to this day.

Water was once relegated to the outskirts of the planet, to the ethereal heights that are the most remote from the center-point of the earth, as it was possessed by a frenzy, with each grain of its substance colliding and striving against every other grain. The clear liquid then grew calmer and was granted permission to approach the surface. It became more orderly, learning to unite its substance to form a denser whole, and thus it gained a more important stature. It was given permission to get closer to the iron core, descending from the heights to occupy the surface of the crust of this young, continuously changing world. It is nonetheless as if this promotion in the great ranking stirred up the ambition of the watery realm. In close contact with parts of the mantle, it then appears to work to further its organization, as if hoping to put other bits of matter behind it in the great ordering. This industrious work is diligently performed by the ocean, with the oceanic crust continuously melted down, returned to the fiery depths, so that the light can be separated

from the heavy, sorting granite from basalt. Each oceanic fault is a blade, cleaving the crust in two, with one offered the lowest position, closest to the core, and the other forced to float above it, more distant from the place toward which all earthly matter is irresistibly attracted.

No matter how diligent the ocean's service to the grand enterprise of the ranking of the earth's substance is, the lightest rocks extracted from the mantle are nonetheless still heavier than water itself, and thus these rocks consistently outrank the clear liquid in the great ordering. As this refining of the mantle by the conjoint work of the currents of lava and those of the oceans continues unabated for innumerable years, the granitic mass floating over the basaltic crust covering the planet steadily grows. The oceans nonetheless successfully slip into the places where such lighter rocks are absent, thus appearing to outrank these islands in terms of heaviness, even though it is not the case. The waters stand side by side with the granitic crust, and this crust even often protrudes from the waters, giving the impression that it would be lighter than the clear liquid, which would be the case if the ranking were absolute, without any other factor influencing it, but this is not the case. These islands standing out of the ocean are the first continents. Their emergence is thus more than a whim of fate, a result of the asperity of the rocky surface of the earth. They are the product of a patient refining of the underlying crust, the heavy floor of the oceans, in which water plays a crucial role. Without the pressure and the cooling power of the watery coat of the planet, this refining would either have been very inefficient or would not have occurred at all.

The dry land is thus born out of the waters, out of the opposition between the earthly fire and the ocean that rained down from the heavens. In the words of Heraclitus: "Opposition brings concord, and out of discord comes the fairest harmony."¹ The disturbance of the previous order prevailing on the surface of the earth by the deluge of rain forming the ocean, the strife between the earthly and the heavenly, fire and water, led to a new concord, with the two opposites begetting a new foundation that in turn will soon allow the emergence of a new world. Continuously refined, sliding back into the infernal abysses, the oceanic crust stays young, frequently reborn out of its own ashes, whereas the byproduct of this refining

¹Original Greek: "τὸ ἀντίξουν συμφέρον, καὶ ἐκ τῶν διαφερόντων καλλίστην ἁρμονίαν." From: Patrick, George Thomas White. *The fragments of the work of Heraclitus of Ephesus on nature*. N. Murray, 1889. Page 127



Figure 6.1: *A Cliff in Brittany, France.*

remains, floating over it, surrounded by water, left largely intact by the passing of time, only eroded by the winds and the rains. The dry isles protruding from the ocean slowly collide, gathered by the currents of the mantle, unhurriedly forming a larger land that became the first continent. This first continent remains largely intact, having only been subsequently cleaved by the work of time and the same currents that led to its formation. One part of this most ancient land, a craton,² is found in the southern tip of Africa (named Kaapvaal), while the other is found on the coast of Australia (the region named Pilbara), and this is why this primordial landmass is known under the name of Vaalbara. Monuments to the long history of the earth, these places would deserve to occupy a more prominent place in the world of our species, as they represent the first home of our lineage found on the dry land, once our forebears crawled out of the waters to seek refuge upon it.

The opposition between magma and water then progressively leads to an opposition between ocean and land, and this contrast soon began to play a decisive role in the appearance of the fairest harmony found in the entirety of the cosmos, as far as we know it: life itself. The location and exact circumstances of the ignition of this

²A craton is an old and stable part of a continent, one that survived the merging and separation of ancient supercontinents.

bedazzling chain reaction, having now conquered most of the face of the dry land and the depths of the seas, are still shrouded in mystery, but it is almost certain that the continents were an important piece of the puzzle of its emergence. Life needed impulses, energy, in order for its first spark to be ignited, and it needed water to articulate its various parts into an animated whole. A wide palette of precise conditions had to be met, and a precisely crafted cradle had to be fashioned by the hands of nature, otherwise, this first spark would neither have been struck nor propagated and turned into a wildfire. What is presumed to be a necessary condition for the appearance of life is a high concentration of the building blocks of the living, and a source of energy, an impulse allowing their assembly, before the resulting beings evolved the capacity to provide for their own needs. The interface between land and seas certainly was a key to this wondrous event.

The shallows are where the land meets the sea, where both mingle, with this locus belonging to both and to neither. Pools of water carved by the rains and the waves adorned the coastlines, like cauldrons wherein the hands of nature could prepare a sacred brew. The first spark may have been kindled near a wound of the earth in the sea, providing ample ingredients, fire, and water, but the coastal pools reunited the same conditions, with the sun bringing its luminous fire, the earth the vessel wherein all could be contained, while the moon acted as invisible hands by causing the ebbs and flows of the tides, twice each day, allowing the other luminary to concentrate the content of the pool by lifting up part of its water, bringing it to the clouds. Earthly and celestial forces thus joined together in this endeavor to create the fairest harmony between them, with connected pools acting like vessels used by a divine alchemist, the father of life. Block by block, the first living being was assembled there, fed with carefully crafted nutrients, allowing it to reproduce in a womb of granite filled with saltwater, laden with a flurry of minerals extracted from the rocks by the waves and the rains, until life could wean itself off this care of nature, spreading out of the rocky cauldrons embedded in the first continent. The first coasts may thus be seen as our first home, just as much as the ocean itself. Long before life set foot on the dry land, the continent already supported us, allowing us to be, like a sturdy hand into which we crawled for safety, enjoying its protection as we were fed by the earth, the sea, the sun, and the moon themselves, as sons of earth and sky.

Under the neatly aligned stones trodden by our feet, and beneath the muddy soil made of the remains of past living things that crumbled to dust long ago, lies the rocky crust of the earth. It bears the towers of stone and steel cherished by our world, without complaints, without receiving the slightest expressions of gratitude from men. It simply occasionally reminds them of its presence by brief tremors shaking up their world to its foundations. As terrifying as the experience of such a trembling of the ground may be, one should embrace such rare occasion to feel the nature of the continent under our feet, not simply as a rigid support for our world, but as the skin of the planet, animated by torrents of molten rocks running in the depths, patiently shaping the basis of all that we build. If we treat earthquakes as a call from the abyssal inferno, the monumental beating of the incandescent heart of the earth, the terror inhabiting the mind of most men witnessing such an event may then vanish into thin air, leaving only awe in front of the power of the earth, able to calmly displace our world as we move a mere object. Letting the tremor pass through us, enthusiastically welcoming its touch, we may feel in harmony with our home, this rocky orb harboring our civilization, the frame of our long history.

The ground beneath our feet nonetheless seems so stable, a wide and sturdy pillar, appearing eternal. Considerably harder and more resilient than our flesh, our heels are powerless to shake or shape it. The mere name of the main constituent of this foundation of our world evokes a remarkable capacity of resistance: granite,³ a rock able to withstand the blows of sharp iron blades and heavy hammers, passing unscathed through the work of time, simply slightly worn down by the winds and the waters. Touching the gritty texture of a piece of granite, we may feel the essence of our continent. Observing it attentively, we may notice the gentle sparkling of the bits of quartz encased in it, and the various shades representing the variety of minerals embedded in this chunk of earth. How heavy this substance feels in our feeble hands! And yet, we should notice that it is the lightest solid layer of our planet. Our entire continent floats above a denser, more massive rocky blanket, made of basalt, a rock rich in magnesium and iron and born from the rapid cooling of the fiery blood of the earth, now forming the floor of the oceans. Furthermore, the oceans themselves are largely responsible for the creation of the land whereon we now stand. The piece of granite in our hand, like

³Granite is an igneous rock mostly composed of feldspar, quartz, mica, and amphibole minerals.

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most of our continents, was formed by the water of the ocean itself. To fathom this, let us picture the open wounds of the earth, the cracks and faults through which the incandescent, crimson blood of our planet comes into contact with the cold seas, with the moon itself agitating the vast expanse of water through the tides' ebbs and flows. This shock between the blazing and the frigid is what turned the magma into granite. This encounter of different elements is what begets the granite supporting our world, lighter than the rest of the mantle, allowing it to float above it, and ultimately, through a long-lasting accumulation, allowing continents to protrude from the wobbling desert of water covering the planet. Feeling the ground with our feet, we touch the gargantuan child of fire and water, the heir of earth and sea. Let us be grateful for this creation of nature, without which we may not be as we are now, proudly standing, erect between earth and sky.

Climbing onto the highlands of the country we inhabit, overlooking wide plains or deep valleys, the incredible extent of the granitic mass forming our continent may begin to be fathomed by our mind. Parts of it may be extremely ancient, far more than the seafloor, continuously being melted down and renewed, but they all float above heavier layers, ranked by the pull of the earth keeping us close to the face of the planet. What we see and touch, this impenetrable kingdom underneath our world, is the lightest solid layer, assembled there by the movements of the mantle, with these floating isles of granite being gathered across the ages, becoming our land, our home. They emerge as a beacon of stability after the first crust was destroyed by the collision that engendered the moon, and the second one was continuously born anew as it, piece by piece, was devoured by the fiery torrents under the seas. We owe the existence of our cities and villages, the evolution of our species into a wide array of cultures and peoples, to the continuous work of ordering the substance of the earth, and we may express our gratitude for this incomparable gift bestowed by the earth upon life.

Strolling on a rocky coast, we behold the slow advance and recession of the sea by the invisible hands of the silvery luminary of the night, the pools of seawater that form, inhabited by hard-shelled creatures wielding the power of rocks to their advantage, for their protection, what we see may be one of the cradles of life itself. The rains and the waves scratch the rocks and allow the minerals encased in them to be poured into the waters. The sun concentrates the content of these pools by robbing them of some of their water,

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while the moon stirs up the tides, allowing a mingling to occur. The continent thus does more than merely support life. It helped to create the conditions for it to appear in the first place, creating places where earthly and heavenly forces could work together to light the first wick of life. Plunging our hands into these pools, feeling the warmth of the sun's envoys imparted to this crystal-clear liquid, tasting its saltiness and the palette of substances suspended in it, we may picture the budding of the first seed of life in such a liminal place, a crossroad of the various forces of nature, recognizing the mark left by each one of them upon our nature. Seeing our true nature, we may acknowledge our debt to the great continents bearing our world, reevaluating our relationship with them, seeing them as parents, as much as a foundation whereon we build up something giving meaning to our existence. It is a mere slab of granite extending to the horizon, indeed, but it is also our inalienable home, born out of the seas, appearing immobile and immortal to our eyes, and yet continuously changing, a manifestation of the fairest harmony begotten by the opposition between fire and water, earth and sea.

Chapter 7

The Great Oxygenation Event

The sky was hazy, perhaps slightly orange, while the ocean was greenish, as they both were laden with substances now rarer in these realms. Above, it was mainly methane,¹ exhaled by the earth itself, while below it was iron and sulfates,² weathered from the continents by the rains. This seemingly bleak landscape was nonetheless teeming with life, inhabited by a great variety of primitive creatures. Purple or green bacteria³ fed on the light of our star and on the breath of the earth, infused in the sea. Floating on the surface, letting themselves be guided by the currents and the tides, and thus indirectly by the strong hands of the moon, they ferociously strove for their survival and patiently found new ways of exploiting the resources available around them. They initially harnessed the power of the blood of the earth, the iron and sulfides dissolved in the water surrounding them, exploiting its energy in conjunction with that of the luminous envoys of the sun to sustain the machinery of their life, to grow, and to multiply.⁴ Perhaps due to a sudden rarefaction of these essential substances, the minute weavers of sunlight nonetheless soon evolved and found a way to dispense with the need for this blood of the earth, to instead make use of the most abundant and

¹Methane: CH₄.

²Sulfates are compounds containing sulfate ions: SO₄²⁻.

³Better known as “cyanobacteria.”

⁴This process is called “anaerobic respiration.” For more information, see: Willey, Joanne, Linda Sherwood, and Christopher J. Woolverton. *Prescott's Microbiology*. 7th ed., McGraw-Hill, 2008. Pages 205–207.

persistently present substance around them: water. The details have yet to be uncovered, but it would seem that such evolution occurred through the borrowing of genes between different species of bacteria, randomly absorbed by one species as it encountered floating remnants of beings with such genes in their environment.⁵ Through this whim of fate, and a patient labor of selection by life, a more refined and complex way of exploiting the brilliance of the sun was discovered, one that used water as a fuel, and incidentally shattered the bonds forming these bits of water, separating its constituents, hydrogen and oxygen, something that would in time radically transform the visage of our planet.

The Chinese philosopher Laozi said that “a journey of a thousand miles begins with a single step,”⁶ and likewise, the origin of the blue planet begins with a single cell, weaving light and water into life, excreting oxygen it extracted from water to rob it of its hydrogen. A single atom expelled from this cell, dissolved in the sea or floating in the air, marks the beginning of a revolution following an important step of life’s evolution. This revolution will nonetheless take time. Its vanguard is swiftly decimated, as the new product of life is highly reactive, binding itself to various substances to form new compounds. In the ocean, these new things attach themselves to the substances upon which the ancestors and cousins of the creature that produced it fed, iron and sulfides. The gift of the light-workers then turns iron into rust, falling on the seafloor, creating crimson bands still visible today in some parts of the earth. In the air, it reacted with methane, forming water on the one hand and what would become the carbon winds on the other (CO₂). The gift of the new generation of light-workers nonetheless soon also reacts with other living beings, but it becomes a terrible poison to many of them, gravely disrupting their internal machinery, irremediably destroying their components, leading to a decimation of numerous branches of life. But once again, with each catastrophe comes an opportunity for an evolution and a strengthening. Life learns to cohabit with this novel and potent substance excreted by the most recent shoots of the tree of life, and it later finds ways to also harness its power.

⁵For more information on the evolution of the mitochondria, see: Raval, Parth K., William F. Martin, and Sven B. Gould. “Mitochondrial Evolution: Gene Shuffling, Endosymbiosis, and Signaling.” *Science Advances*, vol. 9, no. 32, 9 Aug. 2023.

⁶Common paraphrase of the original Chinese: “千里之行，始于足下。” From: 阿部吉雄, 《新釈漢文大系〈7〉 老子 莊子上巻》東京: 明治書院, 1966. Page 109 (Chapter 64).

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As the new generation of light-workers surpasses its parents in efficiency and resilience, it slowly replaces them. These organisms patiently conquer the surface of the ocean and the coasts watered daily by the tides. The byproduct of their industrious labor increases, but vast are the reserves of the substances with which it interacts, and thus, for a considerable number of years, it is only found in negligible quantities in the air and the ocean. Water rains down from the sky as the haze induced by the breath of the earth slowly wanes. The seas' emerald hue becomes increasingly faint as countless revolutions of the earth around the sun are performed, while on the floor, the piles of rust steadily grow. But there comes a fateful day when the minute weavers of light have exhausted the reserves of the heavy breath of the earth made by the seas and the sky. When the gift of the light-workers has nothing left wherewith it can naturally react, this is when it slowly becomes something that is to be stored in the coffers of the ocean, to be kept in the vaults of the sky, dissolved in water or air. When the old merchandise of nature veiling the clarity of the heavens has been completely swept away, the sky and the ocean can finally let their transparency be seen, taking on the appearance that is familiar to us, as the azure dome through which the clouds silently pass, and the cerulean expanse gently undulating under the benevolent gaze of our star. A new dawn rises upon the dwellers of the earth.

The patient, steady conquest of the sky by the gift of the light-workers represents a turning point in the history of our planet. For the first time, life, the middle realm caught between earth and sky, is in a position to play a significant role in the shaping of its environment, on a planetary scale. Life stands up to the earth and the sky themselves, appropriating them, causing them to serve its purpose: its perpetuation and expansion. But the work of this hand of life, shaping nature itself, soon has unintended consequences, as the removal of the old breath of the earth from the air renders it less able to retain the torrid gifts of the sun, and thus a chilly wind blows over the land and the seas, with glaciers and ice caps extending their territory.

Furthermore, high up in the air, a new kind of interaction appears between the envoys of the sun and the ethereal gift of the emerald beings down below. Sun rays vigorously strike the minute molecules suspended near the frontier between earth and space, two atoms of oxygen bound to one another to appease their uncontrollable force of attraction. Such energetic collisions rupture this bond

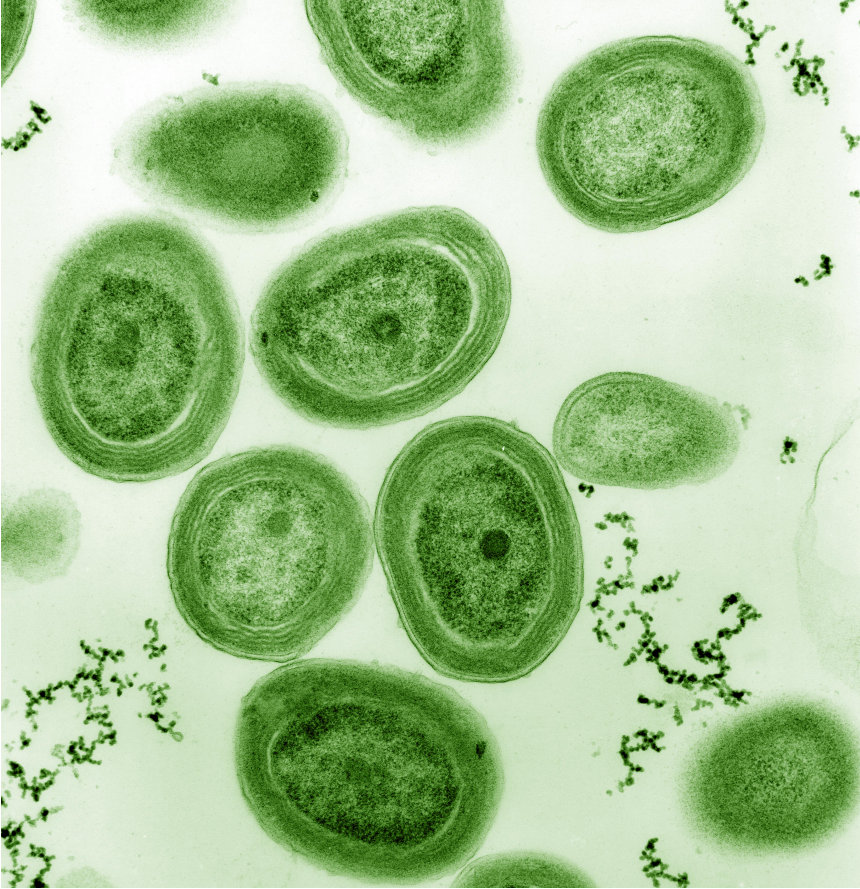


Figure 7.1: *Green bacteria.* (*Prochlorococcus marinus*)

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and invite the formation of new groupings of three atoms, better known as ozone (O^3). This new compound is made of the same building blocks as before, the gift of the emerald beings, but it reacts differently to the envoys of the daystar. They act as an invisible sieve, filtering some of the most violent rays reaching our planet, whose tint goes beyond the limits of our vision, beyond the violet color of its spectrum. The force of some of these grains of light may be so strong as to burn the skin of the living, without these luminous specks being seen, but through the agency of this new upper layer of the heavens, blocking this potentially harmful display of stellar brilliance, life finds itself protected. Fashioned by life and for life, it is a shield from the wrath of our star, letting the softer part of its shine pass through, allowing countless branches of life to feast on the glow of its benevolent envoys, while defending it from an overbearing radiance that would ruin these efforts of the living. The material forming this shield (O^3) is itself heavier than the one out of which it was formed (O^2), and thus, according to the great ordering of all earthly matter, one might have expected to see it sink below it, closer to the ground rather than out on the edge of space, but the density of this protective film is so low that it allows this protective film to remain stable, near the edge of space, faithfully defending the living beings out of which its building blocks came.

It took an entire eon for life to operate this audacious conquest of the lower heavens, but once this conquest was firmly consolidated, the middle realm had a free rein for its expansion. It thereby grew stronger and more resilient than ever. Life is nonetheless not alone. Its rule is far from supreme. The earth remains active, and it continuously interacts with the transparent reserve built by life in the sky. What life has built, the earth can snatch away, in the same manner as life robbed the old sky of its wealth to make way for its own reserve. When thunder strikes the remnants of past living things and ignites them, their combustion consumes the wealth stored under the blue dome. The same goes when the dead decay on the face of the earth or the seas, slowly reacting with the substance of the air, or when previously-buried rocks are exposed to the celestial aether by the movements of the crust, by the opening of fresh wounds upon its skin, causing minerals to capture the gift of the light-workers, thereby producing a wide array of new rocks. But life itself soon becomes a major consumer of the newfound wealth of the heavens, as young branches soon grow on the tree of life, such as the one to which we belong: animals, creatures relying on the content of the

heavenly vaults, oxy-gen, to power their movements and fuel the fire of their life. The plants, on the other hand, represent an evolution of the primitive creatures that initiated this transformation of the seas and the sky. What the plants crave indeed is the opposite what animals crave. It is the carbon winds (CO_2) that plants exhale, whereas animals breathe out oxy-gen, replenishing the celestial vault, whose content is slowly consumed by animals. A delicate balance is then found between the earth, life, and the sky, maintaining a relative status quo, allowing the middle realm to prosper, paving the way for a future conquest of the sky by animals, and giving the earth its so unique, so mystifying complexion.

Beholding the cerulean splendors encompassing our world, the vast dome out of which we draw our breath, and the undulant expanse of water surrounding our world on all sides, source of the rivers we use to alleviate our thirst, it may seem hard to believe that when our most distant forebears were still rudimentary organisms floating in the shallows of the ocean, these realms had yet to be adorned with their coat of blue. The sky was hazy, and the sea troubled, embroidered with threads of iron and sulfur, a greenish tapestry that would appear gloomy to our eyes. The source of this titanic transformation of the sky and the seas is nonetheless found within the tree of life itself, in the middle realm caught between these two others. Wandering on a coast where the work of agitation of the moon is dampened by the land, we may stumble upon the distant descendants of those responsible for the great mutation of the heavens and the ocean. Humble creatures, appearing like a green foam on the surface of calm waters, these beings form an agglutination of cells patiently weaving air, water, and light into new leaves of the tree of life. They consume the carbon winds found in the air, and before that, other gases breathed out by the earth itself,⁷ and excrete as a result of their diligent work the very substance craved by our lungs, oxygen, causing us to instinctively inhale the content of the lower heavens, now indispensable for our survival. Taking a deep breath, feeling the air entering through our nose and departing from our mouths, after having let for a brief instant our body operate its invisible work of alchemy, we may remember that the wealth of energy found in this air, exploited by our flesh, was offered to us by humble

⁷This process is called “anaerobic respiration.” For more information, see: Willey, Joanne, Linda Sherwood, and Christopher J. Woolverton. *Prescott’s Microbiology*. 7th ed., McGraw-Hill, 2008. Pages 205–207.

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creatures such as these, so weak in stature, but whose strength came with numbers and time, wherewith they radically changed the entire planet. Let us pay a vibrant homage to their remarkable efforts and be grateful for their priceless gift.

The completion of the feat represented by the transformation of the heavens nonetheless took considerable time. Exploring cliff-sides, cracks in the skin of the planet, we may be given the chance to observe the inconspicuous traces of this change. Crimson bands stacked about one another, buried under layers upon layers of other sediments, represent as many chapters in the great history of the earth. These are made of rust, born when iron, a major component of the substance of the planet, received the gift of the ancient light-workers; when it absorbed the reactive element they excreted. We may witness the formation of the blood-colored powder on the things of the world around us now, traces of the capacity of this gift to act upon the most abundant of all metals, the material out of which the deepest foundation of the earth is made. When we observe such interaction, we witness the earth capturing the wealth of the heavens, placed there by life itself. This is how these bands in the ground formed, with grains of iron suspended in the ocean snatching these energetic elements, binding with them, and thus gaining mass, causing them to sink in the dark abysses, buried for eons until the earth itself revealed its wounds to our inquisitive eyes. Seeing the corrosive effect the air has upon our world, we may thus ponder the play of forces between the earth, life, and the sky. What is an absolute necessity for us, the most precious of all presents, may nonetheless also be a poison slowly eating away at other things. Even inside our body, the vivifying nature of the secretion of the light-workers also comes with a price to pay. Such corrosion also affects us as we age, slowly wearing us down, destroying minuscule bits of ourselves, and spoiling our beauty. This may be seen as a necessary balance, the establishment of an equilibrium necessary for life to prosper, with something that must be taken away when one receives a gift. The flame of life burns within us, fed by the air and its gift, but it also consumes us, bringing us closer to the earth with each breath. Just like bits of iron left exposed to the elements, we also will one day be taken back to the ground, after having enjoyed the riches of the heavens.

A lesson is taught to us by the emerald beings weaving air, light, earth, and water into life and thereby feeding us with their leaves, their seeds, or their fruits, beings also offering us the air that we

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breathe, the power that comes from persistence, and the union of the weak, the insignificant. If single cells can profoundly change the earth and the sky, what could humanity accomplish? These minuscule organisms cleared up the sky, allowing us to contemplate the elegance of the stars, the enchanting nature of the sunrise, but what have we offered to other branches of the tree of life? What is in our power, and how could we benefit the entirety of the middle realm caught between earth and sky? Watching a flame burning the gift of the light-workers stored in the sky, or observing the green canopy of a forest, picturing it replenishing the wealth of life in the vaults of the heavens, at this very moment, as it emanates what we and other animals so desperately need to breathe, we shall pledge our service to the whole we form, striving to also bring a valuable contribution, to repay in full and even more the benevolence we experience from the humblest of all the living. This may be done firstly by respecting our common home, by finding harmony with the planet harboring our world, a noble endeavor that should always remain present in the foreground of our mind.

Chapter 8

The Snowball Earth

The surface of the earth is the scene of a constant tug of war, between order and chaos, between earth and sky, and numerous other forces that continuously redefine its contours and leave their mark upon it. Life itself is one such forces. At this point in its history, its stature is still modest in comparison with the greatness of the other, more ancient ones it faces. Life was nonetheless profoundly affected by the play of forces surrounding it during its infancy. Earth and sky not only gave birth to it. They were its diligent parents, nurturing its growth, pruning its branches, forcing it to endure trials that would allow it to surpass increasingly massive obstacles. One significant factor to which life is very sensitive is the temperature of its environment, the level of commotion reigning between its most minute constituents. If it is too low, the machinery of life is brought to a standstill and crumbles, with its countless pieces unable to move and play their part for the subsistence of the whole, and if it is too high, the machinery breaks down, its minuscule and extremely delicate pieces are torn apart by the excessive agitation. The earth and the sky are indifferent to such conditions. They impassively pass through time, welcoming extreme variations, while the living have to adapt or perish.

The climate of the surface of our home planet is partly defined by its course around the sun, causing the disparity between the seasons. It is also influenced by the incandescent nature of its mantle and core, slowly growing colder as the ages succeed one another. In addition to these relatively fixed frames of the climate, a decisive factor determining its nature is the capacity of the air enfolding the

planet to capture and retain the radiance of the star around which it circumbulates yearly. This is mainly done through the so-called greenhouse gases, mainly carbon dioxide (CO₂), which is also a key element in the cycle of life. When the concentration of this carbon wind is elevated, sun rays are absorbed by the air, and their heat is trapped in the lower heavens, prevented from being diffused in the cold depths of space. These gases are mainly the breath of the earth itself, exhaled through apertures found upon its skin, volcanoes, oceanic vents, or faults in the crust. Every day, the planet breathes out such winds laden with carbon, which are poured into the air, each particle becoming a minuscule trap for the blazing envoys of the sun. Fortunately, this accumulation is counterbalanced by a depletion. The earth breathes out, but it also absorbs back, through different pathways.

The carbon winds blowing over the globe may nonetheless also be consumed, balancing the breathing out of the earth. Life itself is mainly built from it. Contrary to our intuition, most of the substance of the plants and algae giving the planet its emerald hue, besides water, indeed does not come from the ground or the seas, but rather from the air. The carbon winds enfolding our world are a storehouse of the building blocks of life, with this carbon forming the backbone of all living things, from the simplest cell to the most massive animal. But life has, at this point, yet to fully blossom, and thus its breath remains relatively weak compared to other forces consuming the substance of the air. The major way by which the carbon winds are consumed then begins with the heavens themselves delivering their watery substance to the rocky ground, by pouring down rains heavily laden with this element. Rendered acidic by this addition, these rains react with the silicate minerals present on the surface, and the carbon they contain is thereby captured by the rock.¹ The more numerous these interactions between the acidic rains and the silicate rocks, the more carbon is captured from the heavens, and thus the capacity of the upper realm to imprison the shining envoys of the sun finds itself proportionally diminished.

A balance between capture and release, heat and cold, emitting and absorbing, was usually found by nature, but order is always interrupted by transient disorder, sooner or later. The earth is at

¹This process is called silicate weathering. It removes carbon dioxide (CO₂) from the atmosphere and sequesters it in solid carbonate minerals like calcite (CaCO₃) or magnesite (MgCO₃). For calcium silicate, the reaction formula is: CaSiO₃ + CO₂ → CaCO₃ + SiO₂.

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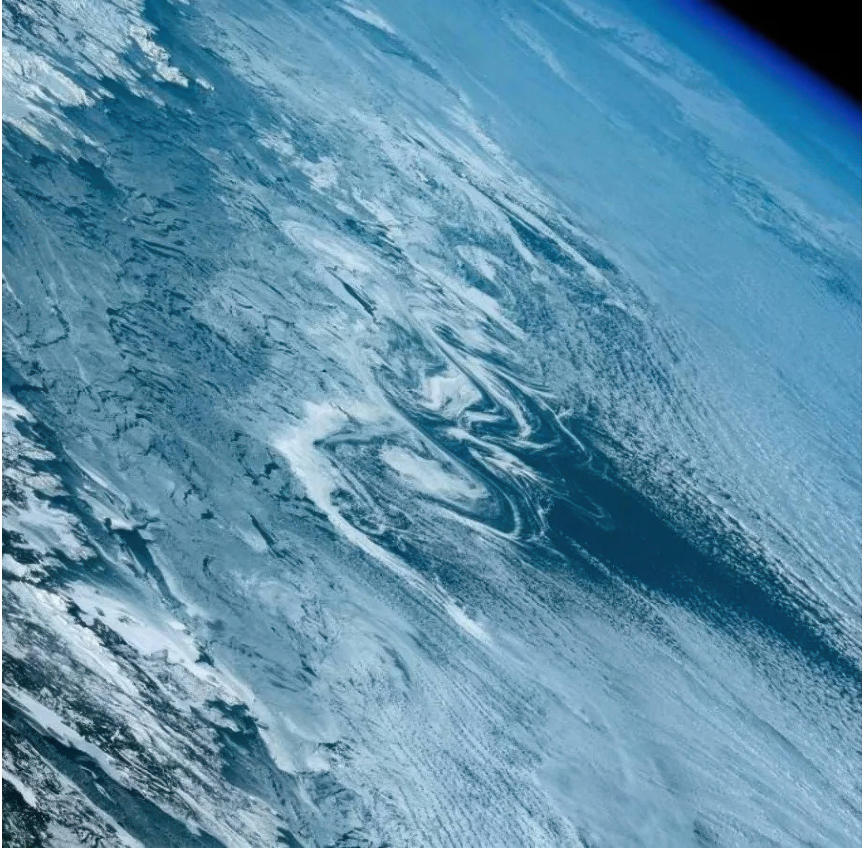


Figure 8.1: *Frozen Ocean Seen from Space.* (NASA)

this point still largely covered by the great ocean that fell down from the heavens. A single landmass has coalesced near the equator, the warm belt of the earth. The sheer mass of such a gathering implies less activity in this great continent, with the blood of the planet more rarely erupting from it, and fewer wounds out of which it would ooze. This, in turn, implies a slower and less deep breathing of the earth, which should normally alleviate its fever. The location of this great continent nonetheless opposes this effect, as the torridity and humidity of the tropics cause an abundance of rain, leading to heavy weathering, and thus a rapid capture of the carbon winds blowing over the earth. Wind is turned to stone, piled up upon the ground in inconspicuous arrays, blending in with the rest of the crust. As this limestone (CaCO_3) foundation was laid upon the ground, the heavens were slowly emptied of their traps for heat, their snares for sunlight. As a result, the warmth of the earth escaped, fleeing to the cold emptiness of the cosmos, leaving the planet more orderly, with less commotion, but also rendering it more hostile to life.

The earth then grows cold. Winter becomes harsh, with the ice caps eating away at the oceans a little more with each revolution of this world around the sun. The carpet of snow laid over the great continent took an increasingly long time to be stripped away at the approach of the spring, and it appeared earlier and earlier in the fall, blurring the line between the seasons. The tropical paradise, the azure ocean surrounding a land of emerald and gold, progressively turned into a mirror. Our planet became a sphere of white glass, reflecting the radiance of our star rather than capturing it to warm its surface, sending the luminous envoys of the sun back to their source, or scattering them randomly, inviting them to illuminate the darkest abysses standing in front of its surface on all sides. As a result of this rejection of the gift of the blazing star, the earth grew even colder, starting a vicious circle, slowly freezing its surface. The final blow came when a colossal eruption of basalt occurred in a part of the great continent, the remains of which are now located in Canada.² This eruption would appear to have considerably enhanced the capture of the carbon winds, greatly hastening the conquest of the earth by the cold. Ice then held sway over most

²This location is called the “Franklin Large Igneous Province” by geologists. See: Wei-Haas, Maya. “Massive Lava Outburst May Have Led to Snowball Earth.” *Science*, 12 July 2023, which is a vulgarization based on the following article: Rainbird, Robert H., and David C. Leckie. “New U-Pb CA-ID TIMS Zircon Ages Implicate the Franklin LIP as the Proximal Trigger for the Sturtian Snowball Earth Event.” *Precambrian Research*, vol. X, no. Y, 2023. Pages A-B.

of the ocean, and the snow covered most of the land. The earth became a giant snowball, a seemingly dead orb of ice circling a sphere of fire.

The earth's visage may have been radically transformed by the ice and the snow, but it was like a thin layer of makeup, applied superficially upon its skin, while the depths of the lower realm remained largely unaffected. The planet preserved its nature. It is life, the middle realm caught between the rigidity of the earth and the ethereal nature of the heavens, that faced a real challenge during this era of ice and snow. Those already present to witness this event and endure the harshness of this long winter were mostly lone cells, accompanied by rarer, primitive multicellular organisms. They often occupied the shallows and the coast, with green bacteria³ feeding on the radiance of the sun, while some ancient microbial lineages still sustained themselves on the breath and blood of the earth, flowing out of vents in the ocean, containing substances whose energy could be harnessed to fan the flames of their life. Rudimentary compared to ourselves and the marvels of evolution that later appeared, these beings nonetheless already represented a real prowess, adapting to changing conditions, reproducing in great numbers, actively striving for their survival, and forming an extremely complex piece of machinery, many aspects of which still escape the grip of our science. For them, the long winter represented a mortal threat, but it also offered life a unique opportunity for growth and evolution. As said by Marcus Aurelius: "What impedes the work advances the work. What stands in the way becomes the way."⁴ These creatures could not understand such reasoning, but they nonetheless instinctively followed the way pointed out to them by the earth and the sky themselves.

Largely deprived of the bountiful gifts of the sun, sent back by the spherical mirror of ice coating the planet, our distant ancestors and cousins were mercilessly culled by the cold. Entire branches may have been trimmed on the tree of life, with the oily envelopes of the cells of these organisms bursting open under the pressure of

³These are more commonly known as "cyanobacteria." For more information concerning these organisms and their role in the Great Oxygenation Event, see: Benton, Michael J., and David A. T. Harper. *Introduction to Paleobiology and the Fossil Record*. 2nd ed., Wiley, 2020. Page 189.

⁴Translation by the author. "καὶ πρὸ ἔργου γίνεται τὸ τοῦ ἔργου τούτου ἐφεκτικὸν καὶ πρὸ ὁδοῦ τὸ τῆς ὁδοῦ ταύτης ἐνστατικόν." From: Marcus Aurelius. *The Meditations of the Emperor Marcus Antoninus*. United Kingdom, Clarendon Press, 1944. Page 88. (Meditations, Book V).

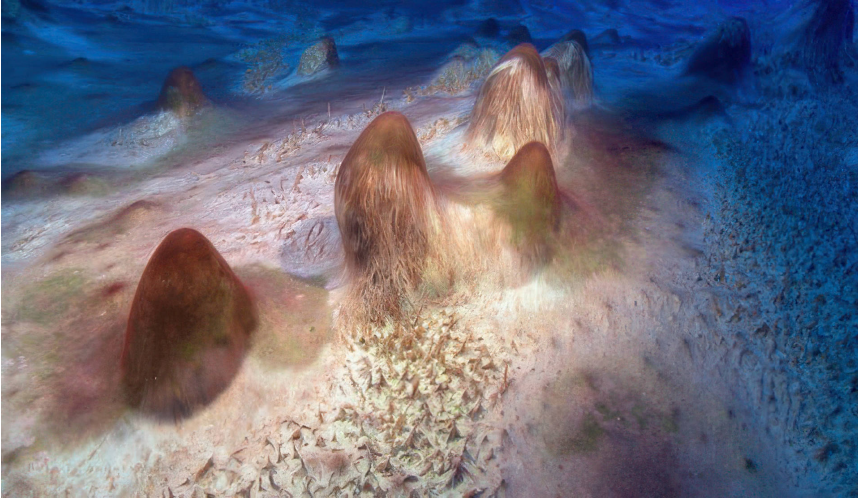


Figure 8.2: *Pinnacles and cones of cyanobacteria along Lake Untersee's bottom, Antarctica. (Picture by Dale Andersen)*

the water they contained, expanding when turning into ice, as if bits of water escaped the enslavement to which they were subjected by these living things, keeping them enclosed in their walls. They thus betrayed their masters to join the gargantuan mass of ice that now conquered the earth, becoming one with it, leaving behind a mere husk, a dead being, a broken piece of machinery. Similarly, the glaciers formed on the continent carved its surface, breaking and pushing the rocky floor to make way for its expansion.

The pressure exerted by the glacial climate upon life was tremendous. It not only affected the amount of light exploitable by algae and bacteria but also vastly reduced the amount of nutrients available to them. Without rains, without torrents and rivers running upon the rocky face of the continent, there is no longer any inflow from the sky and the land to the oceans, where most life at this point resides, crouching beneath the ice or in the rare parts of the coast not controlled by the white kingdom. Plunged in the cold, in the dark, and starving, those living through these times in the frigid waters must fight to escape death. Surrounded by the cadavers of their brethren and cousins, only the most resilient survive and are offered the chance to perpetuate the knowledge of life inscribed in their genes. The incredible pressure favors those who display a particular efficiency in the use of the extremely limited resources available to them. This is why this period marks the taking of a giant step in

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the evolution of life, with the patient refining of various techniques of cooperation and communion between a large number of cells to form a whole that is more than the sum of its parts. But this is only a prelude.

Any imbalance nonetheless sooner or later ends with a return to an equilibrium. The earth covered in ice and without rain, there is no longer any weathering of the rocky ground. The carbon winds sweeping the endless ice sheets are left untouched, carrying their burden without hindrance, without any capture and transformation into limestone of these ethereal currents. The depths of the earth are nonetheless still a round ocean of blazing magma. The planet remains a land of fire buried deep under the ice, still moving, flowing, and breathing out fumes carrying its lightest elements to the heights, soon becoming winds laden with substances and new traps for the luminous envoys of our generous star. This breathing of the earth is that of a sleeping giant rather than that of a frenzied runner, and thus it takes a considerable amount of time for the effect to be noticeable, but there comes a day when the ice begins to thaw, when the snowfalls become rain, marking the beginning of the end of the snowball earth. Hardened by the ordeal, the lone cells are then flooded with nutrients and oxygen offered by the thawing glaciers, causing them to prosper in great numbers, a great spring of life after a seemingly interminable winter. The mirror reflecting the sunlight grew smaller, further increasing its retention, warming the planet. This new season of life was nonetheless relatively short, as the earth once again turned into a land of ice and snow. Like a precious metal refined several times, or a pricey liquor repeatedly distilled, life is shaped by the earth, strengthened, encouraged to evolve through an alternation of demanding challenges and bountiful recompenses. At the end of this era, life will experience an unprecedented bloom, with the appearance of large algae and primitive animals like sponges, our direct ancestors. The earth is nonetheless not done with life. It will continue its work, influencing its growth and the direction it takes, and the effect thereof can still be witnessed around us.

With each revolution of the earth around the daystar, the seamless ballet of the seasons unfolds in front of our eyes. The green canopy of the spring, with its cohorts of newborn creatures cautiously emerging from their den or their nest, soon gives way to the scorching heat of the summer, when water may become more pre-

cious than gold. The crimson shades of the autumn soon follow, proclaiming the great waning of life, announcing the harshness of the frigid winter ahead. The wintertime is a season of challenges, when food, warmth, and light are scarce, but such whims of the climate are not limited to the wheel of the years. Extreme events have occurred all along the planet's long history, even causing the entire planet to be enshrouded in the blanket of ice and snow during innumerable years, but our most remote forefathers nonetheless overcame the most perilous challenges. They survived the harshest of times and thrived as a result of these trials.

The key to the balance between ice and fire is mainly in the hands of the greater earth itself, especially the layer of air coating its hardened surface. Invisible, it is nonetheless present in front of our eyes at all times. It pervades the air around us, in the form of minute traps capable of capturing the rays of the sun. Beholding the azure dome encompassing our world, we may picture the incalculable number of such minuscule traps floating in the air, capturing the star's brilliance, silently absorbing the blazing rays, stealing their warmth, and not letting it go. But what is carried by the winds does not always play the role of such snares. Only those fashioned with certain qualities can perform this task. The breath of the earth is replete with such substances, escaping from the wounds on its crust, thereby causing warmth to accumulate. Our breath is equally able to contribute to this effect. Exhaling air from our lungs, we have unwittingly laden it with a carbon wind, countless minute snares for sunlight, and thus we hold an infinitesimally small and yet real power over the earth, our unique shelter. Taking a deep breath, feeling it depart from us, we may reflect on the effect it has on our surroundings, the benefit or the harm that may come as a result of increased heat.

The release of the carbon winds trapping the luminous fury of the daystar can nonetheless be counterbalanced by its capture. The earth does so with the assistance of the heavens themselves, as they infuse the carbon winds into the dark clouds hovering over the ground, and then pour out the content of their vault onto the surface. Reacting with the rocky ground, the carbon of the rains is held captive by the rock, stored as limestone, stable, able to pass through the ages, intact. We, as mere men, cannot directly perform such imprisonment with our own bodies, but our resourcefulness allows us to foster the capture performed by other living things, endowed with such ability. The emerald workers, the plants, dili-

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gently weave sunlight and elevate themselves using the carbon winds as their building blocks, and thus, by facilitating or nurturing the growth of such branches of life, we contribute to the thinning of the carbon winds, and therefore to the rarefaction of the sunlight traps, thereby slightly cooling the earth. Beholding the jade leaves and blades of these humble creatures, let us ponder their invaluable contribution to the balance between fire and ice, essential to our existence.

There have nonetheless been times when the balance between ice and fire was violently struck by the whims of fate. When the capture of the carbon winds severely outweighs their emergence through the breathing out of the planet, the earth grows cold. The ice then spreads across land and sea, and if left unchecked, as it happened before, the earth turns into a giant snowball. We may imagine what our world would be like if permanently covered with a thick ice sheet and snow. How would we grow our food or raise our cattle? How would we find the warmth needed for us to avoid the cold hands of death? Blinded by a horizon of brightness, a white desert reflecting the shine of our star, how would we adapt to such a trial of nature? Our ancestors nevertheless did. They survived for a considerable number of years in such a terrifying landscape, and this is what made them stronger, what forced them to evolve new traits. They found a novel resilience, forging weapons of war to fight death without mercy. Repeatedly, the entire earth froze and thawed, each time refining life as a whole, trimming this magnificent tree like a skilled gardener. We now carry the indelible traces of these events. The tree of life would certainly be different without these catastrophes, these long rules of the ice and the crushing defeats of the fire. Finding a block of limestone, touching its texture with our fingers, and feeling its weight with our arms, we may see in it the carbon winds, imprisoned in the rock, taken from the sky and made part of the earth. Thus kept away from the heavens, it prevents the sky from holding on to the overbearing radiance of our star. It helps keep our planet cool enough for life to thrive upon its surface, but one day, if the ice once again holds sway over the earth, this vault may be unlocked by the blazing mantle of the earth, releasing its content to the sky, in the hope of breaking the reign of death that would threaten the realm of life. We should be grateful for the balance between ice and fire that now makes our life considerably more comfortable than the life of our valiant ancestors who lived through eras of extreme imbalance, their efforts allowing us to be here today.

Chapter 9

The Breakup of Pangaea

Since its accretion from clouds of stellar dust, the earth has always essentially been a giant sphere of magma running around its center point. Its slow cooling down caused its core to turn into solid metal and its surface to turn into rock, before it was clad with the watery vestment forming the great ocean, but beneath this deceptively inert, rigid, and immutable appearance, the ancient and powerful fluxes of molten rocks and metals still unceasingly and chaotically continue their eternal race, without any goal, and without the slightest reward. This course is nonetheless not without hindrance, as the solid, colder crust can resist the advance of the blazing torrents, even if only slightly, but enough to cause them to oppose their push. When the rocky shell of the planet stands against the progress of its flaming blood, rifts begin to appear, cracks form, and sometimes the red liquid flows upon the land or penetrates the seas. Floating on top of the heavier, oceanic crust, the continents furthermore act as a blanket laid upon the round ember circling the sun, preventing its heat from fleeing into the depths of space, causing it to build up. This accumulation, in turn, weakens the rocky crust. Growing softer, more malleable by the red-hot fingers passing upon it from beneath, the rigid blanket ineluctably breaks, letting columns of plumes escape into the air, or its ruby-colored blood run upon its cold face, becoming an ointment covering it, until it itself becomes one with what it covers, reshaping the dry land.

The tension between the rigid and the fluid, the hot and the cold, the mantle and the crust, is like a never-ending battle. For eons, continents were gathered and formed as plates collided, pushed

by the flow of the inferno, the underworld found deep beneath the ground. Above and under the great ocean, various bits of the broken crust of the planet unceasingly encounter one another, resulting in different consequences, according to the nature of the participants in these duels. These collisions are jousts of the earth, occasions for the plates carried upon the surface of the planet by the currents of magma to measure themselves against others, seeing which one deserves to occupy a position closer to the massive core of the fiery orb—which one is strong, heavy, worthy of being offered closer proximity with the heart of this planet, all of this being part of the great competition that began soon after the birth of the earth: the great ordering of all earthly matter.

The earthly jousts unfold in a timescale that is foreign to us, far exceeding our lifetime, rendering them impossible to witness directly. The traces of the past combats are nonetheless clearly apparent in the ground beneath our world, having shaped the landscapes of some of our lands, monuments to ancient, epic battles between titans made of stone waged long before the dawn of our civilization. The contestants belong to two major categories: the continental ones, whose skin is found above the surface of the great ocean, with this position coming as the result of their lighter stature, and the oceanic ones, occupying the depths, forming the seafloor, younger but sturdier, heavier, and thus bearing the ocean upon their shoulders. When two oceanic ones perform an underwater joust, the lightest, hottest, and youngest one will climb above the other, denser, cooler, and older, sliding above it, accepting its rightful place, behind the strong. When such a joust involves contestants of a different nature, a continental facing an oceanic one, the outcome is without surprises: with its flesh of heavy basalt, the warrior of the depths effortlessly subdues its opponent, a close ally of the air, made of lighter granite, slipping under it and carrying it around as a demonstration of its power. When two continental plates strike one another, something else nonetheless occurs. The old, granitic masses are generally equal to each other in terms of strength. None of them subdues the other, but they rather both let their substance crumple, fusing with the other and letting the line of contact between them grow in thickness until they have exhausted their strength, becoming immobile. The result of such duels, testimonies of such combats, are the mountains adorning our lands, the highest peaks we can climb, showing the continents that collided as equally strong, leaving both standing side by side, like brethren.

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Figure 9.1: *Bridge Between Two Continents*. This picture shows the rift between the Eurasian and North American continental tectonic plates. (Reykjanes peninsula, Iceland. Picture by Chris73)

Representing a discontinuity, a beating of the pulse of the earth arising from the relentless flow of magma enshrouding the iron core of the planet, echoing throughout its long history, the gathering and breakup of the continents then continued, unabated. The passing of time has left puzzles of stones in the ground, for us to decipher, and thus man now knows the course taken by the masses of minerals and metals upon which his world is built. The last beat is nonetheless particularly significant for our species. It not only defined the current contours of our world, shaping the coasts of our fatherland, imparting their shape to the mountains we ascend to experience the greatness of our planet, but it also profoundly shaped life itself, determining the fate of numerous branches, even splitting some of them by creating gigantic rifts separating parts of the populations forming them. The last beat led to the formation of the last supercontinent, uniting almost all the landmasses protruding from the blue, watery desert, bearing the name of Pangaea.¹ This unity was nonetheless transient. The heart of the planet continued its relentless beating, and the continent turned into continents. Unity gave way to diversity, as if the currents of the inferno below had decided to subject the middle realm occupying this land to a trial, to see what contribution to life and the earth each part of this ancient, single kingdom would offer. Borrowing the words of Kahlil Gibran, it was as if the earth itself declared: “Let there be spaces in your togetherness, and let the winds of the heavens dance between you.”² The currents of the seas and the winds of the heavens will accompany the partition of this ancient family, offering each part a space where it will be able to grow and nurture its uniqueness, letting life take different directions. Before affecting life, this transformation nonetheless begins with a profound change in the earth and the seas.

The last great continent formed a barrier hindering the course of the winds circling the globe. Likewise, underwater, it forced the marine currents to bypass it, directly shaping the paths of the seas, greatly influencing the climate of the entire planet. The climate of Pangaea itself reflected a certain level of diversity, but the sheer size of the continent implied that the vast interior land was extremely arid, a giant desert ruled by the fire of the sun by day, and subjugated by cold darkness during the night, an environment far from ideally suited for the thriving of life. Near the equator, monsoons

¹From the Ancient Greek παν- [pan-], meaning “all,” and γαῖα [gaîa], meaning “earth.”

²Kahlil Gibran. *The Prophet*. Alfred A. Knopf. 1923. Page 19 (On Marriage).

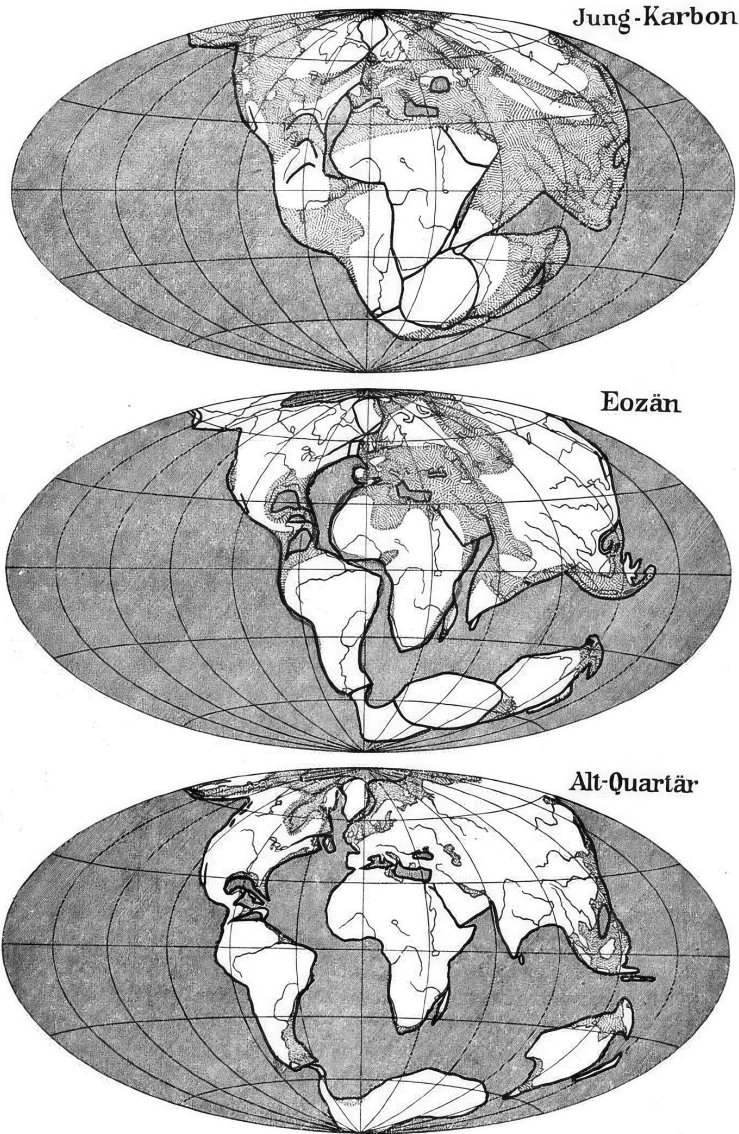
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nonetheless frequently drenched the soil, allowing the formation of vast forests populated by various plants, fungi, and animals. Dinosaurs reigned supreme over the vast landscape of the continent. Sharks and marine crocodiles already roamed the seas. Flying reptiles and insects occupied the lower heavens, while our ancestors were mere rodents, mainly feeding on insects, modest creatures of the night, avoiding the dangers of the day by staying in their lair. A conspicuous absence would nonetheless have been noticed by our eyes, as the continent was then devoid of flowers, which had yet to appear. Ferns and conifers were nonetheless already very much present, painting the humid coasts with shades of green, turning light into life.

The transformation of this landscape begins when the last great continent is first cleaved in two, commonly named Gondwana and Laurasia. As the two masses separated, the ocean rushed between them, creating new currents, both under and above its surface. Parts of the arid, inner desert were profusely watered as a result, and life swiftly followed the sinuous paths traced by the clear liquid sustaining it. For the creatures dominating the seas and the sky, the creation of this new expanse of water only affected them to the extent that it changed the climate of their territory, but for the dwellers of the land, it represented an event of considerable importance, as they could no longer pass from one half of the land to the other. A link between different populations was long-lastingly severed, forcing them, from now on, to walk on different paths, no longer sharing a single destiny. The shattering of the continent's unity was nonetheless also more than a branching of certain parts of life. The separation of the plates indeed caused intense volcanic activity, with the earth heavily breathing its noxious fumes onto the land, letting its fiery blood cover a large part of its face, and causing intense tremors around the new coasts. This commotion of the earth would cause great distress to many species, even extinguishing many of them, cutting off these branches of the tree of life, and letting them return to the earth. This phenomenon intensified as the two landmasses themselves broke into several pieces, forming the continents we know today, slowly drifting away year after year, some of them once again colliding with others.

The newly exposed lands increased the weathering of the crust, capturing more and more of the carbon winds blowing over them, and thereby preventing the retention of the warmth of our star in the heights of the sky. The climate followed increasingly complex

Abb. 4.



Rekonstruktionen der Erdkarte nach der Verschiebungstheorie
für drei Zeiten.

Schraffiert: Tiefsee; punktiert: Flachsee; heutige Konturen und Flüsse nur zum Erkennen.
Gradnetz willkürlich (das heutige von Afrika).

Figure 9.2: *The breakup of Pangaea*. This is the first reconstruction of the breakup of Pangaea, by Alfred Wegener, 1915 (Illustration from: Wegener, Alfred. *Die Entstehung der Kontinente und Ozeane*. Friedr. Vieweg und Sohn, 1915.

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patterns, as new currents were created between the continents, and this, combined with their more diverse location upon the surface of the planet, created a wide diversity of environments, forcing species to adapt to these new conditions or perish, stimulating the further branching of the tree of life. Some of these species nonetheless valiantly overcame all the obstacles standing in their way, even among the youngest shoots of the tree of life, such as flowering plants, which emerged after the breakup of the great continent but are found all over this new world. Their minute seeds were indeed able to ride on the wings of the winds, to be dispersed in the four corners of the planet. Others, however, remained isolated, and this seclusion allowed the birth of a uniqueness. Thus, the marsupials were only found in Madagascar, and the platypuses in the austral lands, until the intervention of man, as they appropriated a specific land, at a specific time, letting their bodies be shaped by their surroundings. Without the breakup of the great continent, these unique animals probably would not have seen the light of day. The wide palette of creatures adorning the lands of our world would have been far narrower, depriving us of the chance to admire these possibilities offered by nature. Although still ongoing, this work of the earth has nonetheless now largely been supplanted by the labor of man, able to shape the realm to which he belongs far more quickly than the planet ever could, for the better and the worse.

Son of the earth and the sky, man nonetheless lives in a world whose pace differs significantly from the pace of the greatest forces surrounding him. His lifespan is but the blink of an eye for the realms above his head and below his feet, and thus his perception of their nature is fundamentally flawed. We see the ground beneath our world as immutable, a permanent fixture of our existence, one that will remain on the day of our passing as it was when we came to be, but if one is perspicacious enough to decode the signs left in the ground, if one learns to read the great book of the earth, written in its crust, then one may finally begin to imagine the course taken by the various lands of our planet. A vast puzzle of rocks, metals, and a myriad of trace elements, this is what the face of the earth is, a puzzle that reveals its nature, and tells the tale of its becoming. It took a considerable amount of time for our species to even realize the existence of this puzzle, as men first needed a more global vision of the planet, contemplating the shape of all the continents of the earth on a map after having spent great effort to draw

the contours of all the lands around which they navigated. Observing such a world map, we may see what tickled their curiosity, as various pieces of the continents facing each other seem to possess remarkably complementary shapes, one fitting into the other if they were to be brought closer. Confirmed by the signs written in the ground itself, as fossils of extinct species or precise arrangements of elements betraying a common origin, the story of the earth began to be recounted in man's world, shattering one of its foundation stones, revealing an ancient misconception: the ground beneath our feet is not an immobile slab, but rather is continually in motion. The continents unite and break up. They encounter one another, forming large mountain ranges, or they separate, isolating those inhabiting them from their brethren and cousins. Feeling the rigidity and apparent immobility of the soil whereon we stand, let us now be reminded that the entire crust is on a continuous journey across the face of the earth, still ongoing right now, at a pace of the width of a finger each year. Watching our fingers, we may consider the astronomical amount of time that it thus took for our continent to be so remote from the others, offering us a glimpse of the insignificance of our lifespan in front of the long existence of our planet.³

Imperceptible by our senses, and unfolding at a pace far too slow to be experienced directly, we are forced to use the power of our mind and our imagination to discover the story of the continents. No matter where we stand upon the earth, the piece of ground supporting us was once part of a single continent. Our lands, now separated by seas and oceans, were all united, gathered by a discreet but titanic force, the currents of magma flowing deep under them. Our distant terrestrial ancestors and cousins all lived in such a world, that we now name "Pangaea," all sharing a single land, able to pass from one region to another. What has been granted the force to gather can nonetheless scatter as well, and thus, this continent one day began to be cleaved by the work of the blazing blood of the planet. The first part, Laurasia, was formed with what is now North America, Europe, and Asia. It slowly drifted away from Gondwana, composed of South America, Africa, Australia, India, and Antarctica. One world gave birth to a plurality of worlds, with branches of life ineluctably growing apart due to the presence of the ocean separating them. We may imagine the force exerted by the rivers of magma to displace these massive continents, and we may honor the strength of our planet, without which we would not stand here today. Considering

³The breaking of Pangaea occurred around 200 million years ago.

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our homeland, we shall realize that it was shaped by these chaotic currents. Its mountains were formed by encounters between pieces of the crust of the planet, set in motion by this fiery underworld, while some of the coasts mark the locus of a breaking point, where the crust was weakened by excessive heat, unable to escape without bursting through the rocky ground, creating this landscape. Seeing these monuments of the earth, we should remember their origin, the force that gave birth to them, and keep in mind the fact that these are far from eternal. These lands shall one day be torn apart, as they continue to wander over the face of the earth. Let us appreciate the chance we have of enjoying the stability they offer us now. They represent a foundation of our existence, eternal in our eyes, but fleeting for the planet itself.

We now inhabit a world that has built bridges between the most distant continents, allowing creatures and things to flow unimpeded between them, but these are the result of recent inventions. Isles of granite protruding from the oceans, resting on a crust of basalt, each continent once formed a singular world, with a unique climate, a distinct flora and fauna, each representing a path taken by life itself, an exploration of a realm of possibilities it offers. Grabbing a tomato or a corn kernel, we can ponder on the fact that these are the fruits of the Americas, species that grew nowhere else before men from the other side of the ocean navigated there and transplanted them into their homeland. Without the rift between the two sides of the Atlantic, such plants may not have seen the light of day. They are the product of a conjunction of conditions inextricably linked with the location and the nature of the land where they appeared. Through separation and distance, life is given space to explore itself, and when the chasms are mended, when bridges are built between the isles, then we can reap the fruits of this long separation and appreciate the role it played in their emergence. Picturing the long chain of causes having led to the appearance of these plants and animals tied to a specific continent, imagining the vast torrents of magma patiently tearing apart the once unique landmass and patiently scattering its pieces all around the globe, offering them different environments, different relationships with the heavenly forces, we may be appreciative of this unceasing labor of the earth. Recent generations have now gathered all that was separated. They have frantically harvested the diversity that had been sown by the earth itself long before we stood erect upon the earth, and we may thus wonder how to further the nurturing of such diversity now that we

have artificially pieced the puzzle formed by the continents back together. We shall learn the lesson thereby taught to us by our planet, and we shall also realize that division may be a prelude to an emergence, a necessity that fosters healthy growth. Beholding the wonders of the earth, we may then decide to create rifts within our world, imitating the lower realm, as the pieces of its earthly foundations continue to drift further apart, until a precise day, when they shall meet again. We cannot feel the movements of the earth, but let us nonetheless keep in mind that the permanence and stability of our land are but an illusion. We are perpetually on the move, still guided by the impulse that led to the breakup of the great continent, and this shall continue as long as we inhabit the surface of our magnificent planet.

Chapter 10

The Last Glacial Period

The fabric of space remains elusive to our eyes, but we and our planet persistently deform it by our mere presence. This deformation is the source of an attraction between all massive bodies, following the inclination of space itself, driving matter toward matter, until these pieces form an indistinguishable whole. The earth endlessly circles the sun, guided by the mysterious impulse that led to its formation, but it remains affected by the presence of all that surrounds it: its moon and the other planets caught in the grip of our star. We witness each day the rotation of the earth around itself, and we perceive the pace of the seasons marking its revolutions around the sun, but it is also entangled in more subtle ways with its environment. The moon does more than raise the tides and veil its ashy complexion, once defining the rhythm of the months. It, together with other celestial bodies, on the scale of thousands of lifetimes, influences the movements of the planet around itself, causing its axis to slightly wobble,¹ and cyclically changing its tilt.² The sun and the

¹This phenomenon is known as the “axial precession” of the earth, that is, “the gradual shift in the orientation of Earth’ s rotation axis which traces out a conical path once every ~ 26,000 years. The cause of the Earth’ s precession is the equatorial bulge of the Earth, brought about by the centrifugal force of the rotation, which has changed the Earth from a perfect sphere to a slightly flattened one, thicker across the equator. The attraction of the Moon and Sun on the bulge is the reason which makes the Earth precess.” (From: Heydari-Malayeri, M. *An Etymological Dictionary of Astronomy and Astrophysics English-French-Persian*. Web).

²This is known as the “obliquity” of the earth, that is, “the angle that an object’ s rotational axis makes with its orbital axis. In other words, the angle between its equatorial plane and orbital plane. Same as axial tilt.” (From: Heydari-Malayeri, M. *An Etymological Dictionary of Astronomy and Astrophysics*

other planets also operate minute but far from insignificant changes on our planet's course around the star, following regular patterns. The conjunction of all these cyclic influences, the impulse of these heavenly wheels, can profoundly change the climate reigning upon the surface of the earth, thereby deeply affecting life. This is what led to the last ice age, one of many in the history of the earth, but one that would become a crucial event for mankind, paving the way for the beginning of our (hi)story.

As the first men prudently wandered out of the cradle that saw their coming into being, the African continent, the planet raised up its head, daring to face the blinding countenance of the sun more directly. This boldness led to a milder contrast between the seasons, directly linked with the amplitude of such bowing of the planet to the star. Cooler summers implied less melting of the snow and ice accumulated during winter, and thus the dominion of the white, glacial plains patiently grew year after year. This pearly blanket, in turn, rejected the bright gifts of the star, throwing them back into the depths of space, thereby depriving the earth of their precious warmth, amplifying the cooling of the globe. Ice thus conquered continents, like two legions departing from the poles, establishing a reign of white death, suffocating the living, robbing them of their heat, bringing to a halt the machinery animating their flesh. This conquest occurred as a series of battles waged across ages rather than as a single advance and a total victory. The ice kingdom grew and shrank as the planet was irregularly balanced by the heavenly forces, caught in a gigantic tug of war between the star, the moon, and various planets, its fate in the hands of these distant orbs in the sky.

The ice present on the land may share a common nature with the water forming the seas encompassing it, but both also significantly differ in the way they interact with the earth. Water is indeed fluid and malleable. It bends and never breaks. It envelopes what it touches, only exerting pressure upon what stands beneath it, due to the omnipresent pull of the earth. It may level mountains and carve up the strongest rock if given enough time, but its caresses are tender, and its touch soft. Ice, which is simply water deprived of an internal commotion, on the other hand, exhibits opposite qualities. It is hard and inflexible. It pushes away what it encounters rather than yielding to it. The advancing glaciers thus carve deep valleys

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on the continents, shaping the land with brute force rather than patience, and causing the life that once flourished upon it to waste away and return to the earth, the realm of death.

When this battle began to unfold, our species had already begun its branching into different races as it spread out of its cradle, with groups characterized by peculiarities inherited from parent to child in a definite territory, isolated from others. The richness of our appearances was born during this time when we appropriated most of the face of our planet. As the ice slowly invaded the continents from the poles, early men nonetheless faced increasing challenges. The cold exerted considerable pressure, not only upon them, but upon life as a whole. Indeed, as man entirely depends upon other living things to sustain his body, needing the power of the plants interlacing earth, water, light, and air to create food, or the flesh of animals feeding upon them, he thus found himself threatened by this pressure. But the only constant in life is change. Encountering an obstacle is an opportunity to find a new force within oneself, to unearth the will to transform one's nature, so that it may be overcome. Subtly pulling upon the threads of force of the earth like a puppeteer, the celestial bodies surrounding the earth thus indirectly stirred the course taken by mankind, forcing us to face new trials that would make us who we are now.

The world of man was then relatively rudimentary. He had learned to fashion and use tools of stone and bones to slash or pierce the skin of his prey. He inhabited caves carved by the elements on the side of cliffs and other natural shelters found in his land, allowing him to take refuge from the hostility of the heavens, the chilling winds and the torrential rains, in addition to creating a barrier between his skin and the razor-sharp teeth and claws of the ferocious beasts sharing with him a territory. Facing deadly winters, forced to wage a war against the heavens and the earth around him for his survival, among depleted resources and constant threats of extinction of the fire of life, man had no choice but to devise ways to complement what life had given him, to supplement the weaknesses of his body with tools of his own making, so that he may stand a chance in front of the white walls advancing toward him, wanting him to return to absolute darkness. Denied fur on his skin, he would steal one of the wild beasts, sawing various pieces to fit his frame. Battling against ice, he would wield fire, a gift of the heavens offered by thunderbolts striking the pillars of life forming the forests, burning the cadavers of the middle realm to prevent him from being forced



Figure 10.1: *Life in Nunavut, Canada.*

to join the one below. With prey and fruit gathering spots becoming scarcer, he had to learn to unite his strength and his wit with those of his neighbors, developing resilient communities. Patiently, man was kneaded like a piece of dough by the hands of the heavens and the earth, made stronger, more resistant to the whims of fate. His inner world expanded as the glaciers advanced, shaping his species, just as the previous challenges experienced by his distant ancestors made him who he is.

The seemingly ineluctable expansion of the white kingdom then caused a fleeing of the seas from the continents, as their substance joined the new snowy realm, recognizing their common nature. As the waters turned to ice, the shallows were increasingly laid bare, their liquid vestment slowly taken off them. Due to the recession of the waters, new land bridges appeared, connecting parts of the dry land that were previously separated by them. For the first time, men could venture into the American continent from Asia, simply walking, discovering new lands, and settling into a new world. Animals and plants also spread through these passages, creating new contacts between species. The separation initiated by the drifting of the continents thus begins to be reversed, but this further increases the diversification of life, as these species that had ample time to develop a uniqueness during their seclusion can now benefit from a new, stimulating, and challenging environment.

The era of the last glaciation was nonetheless not only marked

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by a considerable expansion of the ice kingdom over the earth. The celestial tug of war also caused an increased variability of the seasons, an unstable climate that forced not only an adaptation to the cold, but also a rapid retreat of the glaciers, with coasts swiftly redrawn, and entire territories flooded, buried in the sea. Forced to be more mobile, men and animals had to migrate according to the whims of the planet. There nonetheless ultimately came a time when the retreats of the ice became permanent, when the sun seemed to increasingly hold sway over the earth. The heavenly tug of war grew calmer, and the planet once again bowed to the blazing orb around which it revolves. The seasons became more predictable. The air became warmer as the glacial mountains slowly fled back to the poles, their substance abandoning them, running hastily toward the ocean. Men and beasts reconquered the land once again laid bare, in the direction of the poles, following the trail of greenery, the vanguard of life preceding them, but they had to find higher ground as the oceans bulged from the influx of deserters from the glaciers, thawed waters flowing back to the place of their origin. They learned from the lessons offered to them by the earth and the sky, and when this ice age ended, they became ready to lay the first stones of human civilization. They began to till this freshly thawed ground and take charge of the nurturing of the tree of life, to take control of the growing of the plants they need to survive. They tamed the wild beasts, enclosing them in pens and breeding them for their flesh, their wool, or their eggs. Having realized the great unpredictability of nature, they decided to create what they needed, and no longer simply wait for the earth to provide for them. The era of the kingdom of ice paradoxically became an invaluable gift, fostering a renewal, triggering the laying of the foundation stones of what would ultimately become our modern world, all of this because of the imperceptible influence of distant celestial bodies.

The giant sphere of sapphire and emerald carrying us around the daystar bows toward the luminous regent, letting its pate be illuminated, and the dwellers of its face experience the contrast of the four seasons. Enormous in our eyes, our home is nonetheless of a meager stature in front of some of its neighbors: the sun itself, Jupiter, or Saturn, so far away and yet deforming the fabric of the heavens by their mere presence, irresistibly attracting our world toward them. The firstborn of our planet, the moon, offers some stability to its mother, who embraces its progeny in its invisible arms, limiting its

wobbling, but it remains permanently caught in a titanic tug of war, being erratically balanced by its impressive neighbors. This celestial battle is nonetheless not only a matter concerning the heavenly bodies. It directly affects us, even though the horizon of our senses is too limited to perceive its unfolding. The clemency of the climate we now enjoy, allowing life to thrive upon the earth and man to hold sway over his increasingly massive world, is a direct consequence of a transient equilibrium between the forces here at play. Observing the sun and the moon, the planets timidly displaying their shining countenance above the horizon, while the turning of the earth is witnessed through their movements, we may picture the subtle bending of the fabric of the sky, softly stirring up the course of our planet, influencing its inclination toward the star and the way it wobbles as it spins. Beholding the power of the celestial bodies around us right now, we may also consider how this heavenly game regularly transformed our lands into vast expanses of ice and snow, triggering ice ages, causing a profound disarray among the living.

The last ice age nonetheless paved the way for the emergence of the world as we know it. It was a terribly challenging time for our species, with entire peoples driven to extinction, and life brutally winnowed by ice and cold, but those who survived this interminable ordeal were forced to overcome the limits of their knowledge and surpass their own strengths. Our ancestors bravely fought and won, making us who we are today. The tales of their combat during the absolute reign of the ice have faded into oblivion, as each subsequent generation enjoyed increasingly better conditions, and failed to relate to the struggles of their parents and therefore neglected the stories of their glorious battles. Regardless of their amount of interest in these accounts of ancient times, they had yet to master the art of etching language upon the earth, so that these tales would resist the passing of time and the neglect of spoiled, ingrate descendants. Signs of these times defining our branch of life nonetheless abound upon the earth, even today. Glaciers of the last ice age have carved many of our valleys and fjords, and the scratches left by their advance on the bedrock remain visible in many parts of the earth. The ice giants indeed walked through the land, pushing mountains away year after year. They carried heavy boulders upon their shoulders, which they left at the end of their great voyage, still standing as testimonies to their journey, lone rocks standing out of relatively flat landscapes.³

³These are called “glacial erratics.” The largest example is the Okotoks Erratic, in Canada, whose mass is estimated at around 16,500 metric tons.

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Encountering such boulders, touching them with our hands, feeling their incredible mass, we may stand in awe of the power of the ice that carried them here, a coalition of mere snowflakes fallen from the sky, joining their forces. This is a demonstration of the power of community, a lesson our forefathers were forced to learn during this epoch of frigid winds and considerable hardships.

Rocks are nonetheless far from being the only monuments attesting to the existence of the last kingdom of ice. Most of the largest bodies of fresh water we are familiar with are the liquid remains of ancient glaciers of this period. When we swim there, our skin in close contact with their silky substance, we bathe in the transparent blood of the ancient giants that carved the valleys around us. When we drink from these pristine sources, we welcome them within us, letting them become part of what we are. We can contemplate these smooth expanses built with the liquid of life, too small to be disturbed by the hands of the moon that raise the tides of the oceans, and yet so great as to be able to quench the thirst of entire peoples for countless generations. All of this, we owe to the celestial tug of war, which has plunged the earth into an era of ice and snow. The calamity of yesterday becomes the blessing of the morrow. What hardened the hearts of our forebears softens ours, as we leisurely spend a day in the presence of this liquid monument, source of delight and contentment.

The traces of the long winter are nonetheless not only found upon the earth. The world of man bears deep marks acquired during those times, and we still reap the fruits that were then sown. The clothes upon our skin represent a clever stratagem employed by our fathers to supplement the deficiencies of our bodies, as they were forced to face an increasingly hostile sky above their heads, and a planet full of enmity beneath their feet. They fought for their lives as the winds and the snow stripped them of their precious heat, and therefore they chose to butcher the wild beasts of their land, wearing their skin and their fur, cut and sewn to fit the frame of their bodies. We are clad with the distant memories of this struggle against the momentary inclemencies of the earth and the sky. Our earthly homes also represent vestiges of the strife against the cold arms of death during the last glaciation. This is when we ceased to rely upon the shelters offered by the earth itself, such as caves, to take charge of the building of our homes, piling up rocks, bones, or wood, insulating the resulting structure with mud, plants, or hides to repel the deadly presence of the dampness of the earth and the air

of the sky, among other threats. Carefully looking at the way our abode is built, we may discern the traces of the knowledge acquired during these troubled times, the layers of material laid upon the walls to form a barrier for heat and cold. Man first developed these techniques to resist the advance of the glaciers. The most important, the most decisive weapons wielded by our fathers to counter the formidable attacks of the ice kingdom may also still be observed within the walls of our home. As a hearth erected in its central part, or as a fickle flame coming out of a device, fire is the ultimate opponent of the ice, and thus its mastery was instrumental to the victory of life over death as cold winds enfolded most of the continents. All of these are the legacy of our valiant ancestors, making our life so much more comfortable than theirs ever was, but even though we are, for now, spared the trials they faced, we shall appreciate their efforts, their gifts to us, as we look around our world and see these faint traces of a distant, troubled age.

Finally, even though the tales of the men and women of the last ice age have long been forgotten, the minds of their authors still left tangible marks upon the earth, miraculously still visible today: paintings in ocher and charcoal upon the walls of deep caves sealed by the earth itself, preserved from the elements before they were recently rediscovered. Attentively looking at these most ancient images, these relics of the most distant past of humanity, let us think of the lives of these people, the obstacles they faced during the great reign of the ice. How different was their life from ours, and yet, in these artworks, we may perceive the products of minds so similar to us, animated by the same desires, inhabiting the same earth and beholding the same stars. We, like them, remain shaped by the work of the earth, and we may thank the heavenly bodies above the horizon, these distant spheres circling the heavens, as they caused the earth to freeze, they incited these men to create these paintings. We may reflect on this when we feel the coldness of the heavens upon our skin, a subtle reminder of the fierceness of nature and the feeble yet resilient nature of our species.

Chapter 11

The Mark of Mankind upon the Earth

Few creatures have been given the power to significantly affect the earth and its ethereal coat, the lower heavens. The first may have been the lone cells floating on the ocean and weaving the brilliance of our star into life, who, through their sheer numbers and inexhaustible patience, turned the coat of the planet into a voluminous reserve of energy available to other forms of life, one from which we are drawing our breath, right now. Following this ancient transformation, only man seems to compare to them in terms of the scale at which he shaped his environment, for the better and the worse. The rise of our species was nonetheless long in the making. During the major part of the time we, humanity, spent on the blue planet, standing upon our two feet, working with rudimentary tools of stone, wood, and bone to survive and engender an offspring, we appeared no different from most other branches of life regarding our relationship with our planet. The imprints we left on the ground were swiftly erased by the rains, and the traces we left in the air were immediately blown away by the winds. As man was subject to the intense pressure of the long reign of the ice, his mind was sharpened, his body hardened, and during these seemingly interminable trials, he drew from within himself the force to begin the construction of a new world, to appropriate the earth, the sky, and even life itself rather than simply live between the realm above and the one below, among the living.

Racing against their peers to find increasingly better ways to

appropriate the earth, men thus intensively explored the possibilities it offered. Rocks were piled up according to precise structures so that men would cease to rely on caves offered by the earth, too scarce and often not ideally located. The ground itself began to appear as a storehouse of resources to be exploited. Metals were then discovered, a hidden wealth of the ground, allowing man to fashion chisels, knives, and swords, further increasing his power, remedying with tools the shortcomings of his feeble body. Equipped with chisels of iron, he could further carve the rocky ground, extracting large blocks that would then become part of his world. Digging deep veins into the ground, ores began to be massively extracted, even causing the collapse of the ground above them. The great, unstoppable march of progress went on, always coming with an inflation of man's world and a plundering of the resources of the planet. A new realm appeared on the face of the earth, competing with life to occupy the space between earth and sky, slowly eating away the territory and substance of what is above and below it.

As man's knowledge of the planet became more comprehensive, the ground ceased to be the foundation of his life, the basis of his being, and it became limestone, granite, marble, gold, silver, and iron, ready to be extracted and brought into his world, becoming part of it. A decisive moment came with his furthering of his appropriation of fire, discovering how to harness the strength stored inside the sooty ashes of past living things buried in the earth. Robbing the graves of his distant ancestors and cousins, the coal and oil forming large deposits in the soil, he burned them away to power his unquenchable ambition, relying on the strength of these phantoms of the past to further pillage the earth and inflate his kingdom, filled with innumerable things. Ardent flames then set machines in motion, relieving man of the need to shape the earth by the strength of his own arms. His power then continues to grow at the same pace as his ambitions, and the range of his work was broadened. In addition to the wealth of the soil, rivers and seas also become the object of his attention. He builds up large dams, flooding entire regions to use the force of the flow of the waters pulled to the sea by the earth itself to power his world. He digs up channels connecting bodies of water previously separated, altering the path of the waters, transforming the fluid garment of the planet. Seen from man's own eyes, it would seem that the planet itself were its subject, its plaything.

The earth nonetheless remains impassive to the unrivaled audacity of man. It feels nothing and holds no grudge against these



Figure 11.1: *Shanghai, China*

minuscule living beings scuttling upon its rugose surface. It offers its body to be used by the living. Only man himself will one day be terrified by the desolation brought on by humanity itself. Only he will attempt to remedy the destruction caused by his fathers and brethren, but for now, his gaze is focused on the heights he yearns to reach by his compulsive work of construction. He covers the ground with asphalt and builds up cities with concrete. His factories burn the riches of the earth, rejecting noxious fumes into the air, bringing the carbon that was buried for ages to the heavens, joining the winds blowing over earth and sea, but also trapping the luminous envoys of the sun and thereby increasing the fever of the planet. Cities are by themselves islands of heat, with their materials absorbing the brilliance of the sun, not dissipating it as efficiently as the wild earth, untouched by our hands. But even the highest strata of the ethereal coat of the planet have not been spared by the frenzy of our species, as during recent times the ozone layer, a product of the light-workers, was severely damaged by products of our industry,¹ gases rising to the heights, which destroyed this gift of the emerald beings protecting us from the wrath of our star, before it fortunately recovered, due to the realization of the danger it represented and the subsequent banning of the reactive substances responsible for this imprudent attack on the fabric of the lower heavens.

¹These products of the hands of man are known as chlorofluorocarbons (CFCs), that is, a class of hydrocarbons containing carbon (C), hydrogen (H), chlorine (Cl), and fluorine (F).

As man frantically burns the sooty cadavers of ancient living things, ghosts of the past, other compounds based on sulfur and nitrogen also find themselves carried by the winds, joining the clouds overlooking our world.² Dissolved in the rain, brought back to the ground by the pull of the earth, these compounds form acids, corroding what they come into contact with, life and earth alike.³ Higher in the sky, the traces of his passage are already ubiquitous, with dislocated remnants of artificial satellites and vessels haphazardly scattered all around the globe, slowly becoming an increasingly denser veil of metals and plastics enshrouding the planet. From these heights, another consequence of the domination of man over the earth may be observed: even during the darkest hours of the night, the sky still glows on the side of the earth enfolded in the shadow of our star. The gentle glow of the Milky Way has been replaced by minute stars kindled by human hands, myriads of flames flickering all over the world, marking the subjection of the planet to the will of the standing creature.

If one only considers the impact of man upon the earth, he may be considered a scourge, a menace to life, the earth, and the sky. This, however, would be simplistic, as it would ignore what was accomplished through his labor. The earth is exploited indeed, but this exploitation serves the building of a world, and it is through the reflection on the value of this world that a judgment may be made on the worthiness of this enterprise. Humanity has been more than a source of destruction and soiling of nature. Man's world is more than a pile of concrete and roads of asphalt. It is also innumerable immaterial creations, transcending the earth itself, even though this world indubitably rests upon an earthly foundation. The emergence of ideas, sciences and the arts, is only possible because of the large-scale expansion of this world, with individuals focusing on specific tasks. The mere appreciation of the true extent and nature of the earth itself demanded considerable resources, the result of a long history that depends on the availability of the riches of the earth. If the very lines of this book, made as an attempt to foster a stronger link between man and his spherical home, came to be, it is because

²The burning of hydrocarbons produces, in addition to carbon dioxide (CO_2) and water vapor, different compounds such as sulfur dioxide (SO_2), and nitrogen oxides (NO_x).

³Compounds released by the burning of fossil fuels such as sulfur dioxide (SO_2) and nitrogen oxides (NO_x) undergo chemical reactions in the atmosphere, and can be turned into sulfuric acid (H_2SO_4) and nitric acid (HNO_3), rendering the raindrops containing them corrosive.

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of the massive work of construction of the world we live in by our predecessors, which includes the massive and relentless pillaging of the body of this planet.

The story of the earth has been long in the making, far more lengthy than the story of our young branch of the tree of life. Since the day we were born until the present day, it has shown itself as a beacon of stability, a solid and seemingly immutable foundation of our world, something upon which we may steadily rest. The labor of our species, its science, nonetheless reconstituted this ancient story, deciphered from elusive signs embedded in rocks. Men read the earth as a book, meticulously studying its wounds, attentively examining the giant wrinkles betraying its age, or drawing out its blood to trace its course. Walking outside, beholding the scenery waiting for us when we pass the threshold of our home, advancing toward the open air, most will first see the marks of the hands of man, the furrows he traced upon the face of the earth, rather than the earth itself, as it was before the advent of our species. We may compare this work of man to that of other animals: the nests meticulously created by the birds, the burrows dug by rabbits and groundhogs, or the dams constructed by beavers. How harmonious are their creations compared to ours, perfectly blending with their surroundings, and how tiny the product of their limbs is in front of the gargantuan products of the world of man! Let us appreciate the extent of the labor of our fathers, the sheer amount of earth that has been appropriated, displaced, and shaped by them to construct these lofty towers of stone, iron, and glass, turning the flesh of the planet into an unrecognizable creation, serving our purposes. Perhaps more than any other branch of life, we have left our mark upon the ground. This raises a question that we are invited to ponder: shall we be proud of our accomplishments? Or should we lament the use we made of the incomparable power bestowed upon us by life itself?

When seen beyond the narrow horizon of our senses, comparing the extent of the wounds we have inflicted upon the skin of the blue orb to the depths of its body, to the immensity of its span, we should be struck by the realization of our insignificance in front of our grand and magnificent planet. Mere scratches are the deepest quarries we carved upon its face. The web of asphalted roads covering the continents is like an aggregate of threads of the finest silk

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swept away in an instant by the work of the skies. Skyscrapers, the pride of mankind, are fluff growing out of the earth, without being noticed, soon wasting away and engulfed by the ground whence they came. The dark smog enfolding cities shall one day be scattered by the winds in an instant of the existence of the planet, and soon its substance will once again be captured by the ground.

Considering our footprint on the soil, the seas, and the air, the extent to which we contribute to the woes affecting our surroundings, life in particular, we are invited to amend our ways, to behave in accordance with our calling, as the sole creatures capable of restraining ourselves in the use of our power, and even willfully to repair the damage done by others. Picturing the long story of the earth, the complexity and patience that led to the possibility of us standing here today, from the gathering of stellar dust having given birth to it, to the present day with a gigantic world erected upon its solid surface, we may contemplate the way we spend each day upon this earth. Are we worthy of the riches it offers us? To reflect on the way we treat the planet providing for our endurance is a first step toward a tightening of our bond with this splendid orb under our feet. All of this history points to the present instant, to ourselves, each one of us, and by keeping the tale of the long journey of the planet always in front of our eyes as we wander over its face, we may truly feel that we belong to the earth. We are not merely living upon this planet. We come out of it and one day shall return to it, one with the whole it forms.

Once our earthly nature has been truly perceived, we no longer see other men as mere vile consumers of the resources of the planet, nor as heroic builders of civilizations standing on it. We see the carbon joining the clouds when we breathe out as a mere movement of the earth within itself. When our world slashes the ground to draw out its treasures, we likewise perceive this as a harmonious swirling of earthly matter, an elegant display, finally seen by our eyes under this new light. Without pride, guilt, or ego, this is how the earth is, and we may benefit from learning from this old body of matter revolving around the sun. With each word we utter, we leave an indelible trace in the earth and the sky, as a ripple in the ground and the air, never disappearing completely. Each letter inscribed upon paper or stone is an imprint of our mind, the seal of being, firmly pressed upon the ground. The sum of all the contributions, the marks of all the men who ever lived, nonetheless failed to alter the course of our planet. It remains a force controlling each aspect

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of our existence, constantly reminding us of its supreme power as it jealously keeps us close to its face, as in a motherly embrace. Too deep to be felt with our skin, we may nonetheless prostrate ourselves on the bare ground, enfolding it with our arms, placing one ear upon its surface, attempting to feel the flow of its blood, the warmth of its heart now, pulling us toward it. Then, as we rise up, we may see our surroundings with different eyes, having let the presence of the earth touch the innermost part of our mind, and letting it linger there.

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Chapter 12

The Destiny of the Earth

The story of the earth may appear to be an extremely lengthy one in our eyes, but its future may be just as long and rich as its past. Reading the book of the earth, written in stone and dust, beneath our feet, we have briefly retraced the steps of its journey throughout the heavens, and this knowledge allows us to infer a general trajectory that it will take, notwithstanding the unforeseeable whims of the sky, the unpredictable which remains firmly anchored in the foundations of the cosmos. The destiny of our planet is nonetheless in great part entangled with the destiny of the star around which it unceasingly revolves, marking the pace of our years. The sun's imprint upon the earth has mostly been left above its surface, as it shaped its climate, its luminous envoys playing with the bits of earth suspended in the air or the matter found upon the ground. It stirred up tempests and abundantly fed the living with its vivifying radiance, offering them an impulse that would set in motion the great machinery they formed, transforming dead earth into the living fire of life. The bulk of the planet nonetheless remains impassive in front of the giant, glowing orb. The impulse animating the rivers of magma in its depths is the result of the friction of its accretion, slowly fading away, radiated in the cold depths of space. The end of the story of the earth will nonetheless almost certainly be linked with the death of the daystar.

Like any other of the myriad of twinkling dots of light adorning the celestial vault, the sun is a transient phenomenon, an event during which a great gathering of the simplest of all elements, hydrogen, collapses upon itself due to the irresistible attraction of matter to

matter. Compressed with an astonishing force, reaching phenomenal temperatures, this mass collapses, fusing and forming a heavier element, helium, releasing light as a byproduct of this violent reaction, the brilliance that reaches us every day. This work of the sun is about halfway done, implying that in a distant future, about the same length of time as the earth has already shone, it will exhaust its reserve. Its radiance will then considerably increase, and it will inflate to monumental proportions, engulfing the planets closest to its surface, Mercury and Venus. The fate of life on earth will then be sealed, as the oceans will evaporate and the continents will be scorched. Not massive enough to explode into a supernova, the star will then die a quiet death, its light slowly dimming into darkness, leaving the earth a cold, desolate sphere revolving around a dead star, only half as massive as it is now. This fate, as gloomy as it appears, is nonetheless one of the most favorable scenarios, a natural death occurring after the longest possible life. A catastrophe may nonetheless affect the planet before this old age.

A repetition of the day the moon was born, the fruit of the union of Earth and Theia, may one day mark the end of our world, a heavenly *tabula rasa* causing the immolation of the tree of life, the planet becoming a clean slate whereon something new will emerge, without us being there. As said by the philosopher Will Durant: "Civilization exists by geological consent, subject to change without notice."¹ Our world stands with the earth as its foundation, and this earth itself stands in the space opened up by the heavens. Man is always at the mercy of these realms, and his fate even entirely depends on the existence of the light-workers weaving the essence of the different realms above and below into life itself, providing him with his daily sustenance. Even the moon, often considered a mere ornament of the night sky, a faint glow guiding our footsteps during the darkest hours, holds a part of the tree of life in its ashy hands. Each year, it further escapes the grip of the earth, by a mere handbreadth, but as the ages will succeed one another, this distance may grow considerable, changing the tides and allowing the sun's influence to grow upon the round dance of these ancient parents.

In the Chthonian depths, the blazing, hardened sphere of iron forming the core of the planet will continue to slowly consume the rivers of magma surrounding it. The solid part of the core will expand, leaving an increasingly small layer of lighter elements flowing

¹Will Durant. "What is Civilization?" *Ladies' Home Journal*, LXIII. N.p, 1946. (The original publication could not be located).

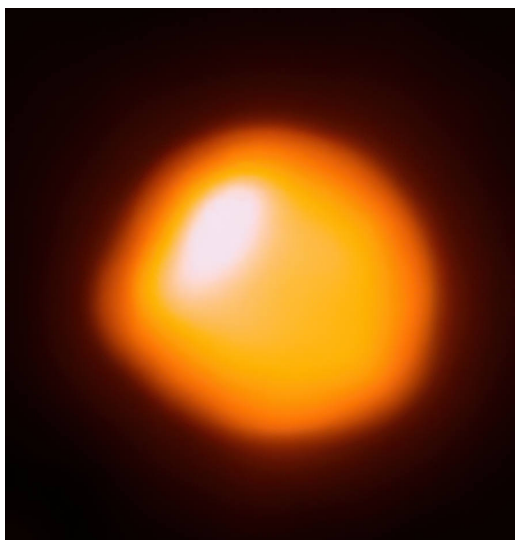


Figure 12.1: *Betelgeuse, the Red Giant*. Clearest picture to date of a Red Giant (Taken with the ALMA telescope, by the European Southern Observatory).

around it, as the heat of the earth is patiently radiated into the emptiness of the cosmos. As this tendency progresses, the movements of the plates forming the upper crust will grow increasingly calm, until they cease completely, bringing to a halt the splitting and collisions destroying and forming new continents. As the flow of the torrents of underground magma wanes to a trickle, the shield of the earth, protecting the living from the brute force of the envoys of the sun, so strong as to damage life instead of fostering its growth, begins to crumble. The magnetic envelope deflecting the strongest rays of the sun will fade away, leaving the tree of life at their mercy, pierced through and through by these minute spears of fire. Life is nonetheless resourceful. It has evolved and adapted to countless challenges, and thus, if it still exists when this shield vanishes, it will certainly create a substitute on its own.

The fate of the earth, this planet upon which our world is built, is ultimately sealed. Its impending doom, the inevitable end to its long story, should nonetheless not plunge us into despair. Every story ends, but its meaning remains, sublimed by its conclusion. The traces of our passage on the earth may be erased by the work of the skies, but what was accomplished on its surface cannot be undone. It forever persists, and it will echo throughout the universe, even if

the cosmos itself fades into nothingness or is gathered into a single point, crushing everything into an unfathomable singularity.

Observing the constant ballet of the celestial bodies surrounding us, the rotation of the heavenly wheels marking the pace of the unfolding of history, the grand nature of this display should inspire awe in our hearts. The earth spins and defines the day. The moon veils its face before discovering it, and it becomes the source of our months, while the circling of our planet around the daystar offers us the succession of the seasons defining the years. Ever-changing and yet seemingly permanent, this choreography is simply too slow for us to properly appreciate its variety and chaotic nature. Glancing at the ashy face of the moon, this glowing sphere showing us the beauty of death, an utter absence of life, we should remember the story of its origin, the day when it was born of violence and fire, as our planet collided with another, a cataclysm that almost instantly transformed its rocky surface into a blaze. Our world may someday end in such an encounter between powers greater than us. A distant asteroid, comet, or planet may already be set on its course toward us, silently advancing through space, ready to wipe out all that our civilization has ever built. Setting our eyes toward the stars and planets displayed at night on the heavenly vault, let us treasure the present day, as we have, for now, been spared by the skies. We may cherish this moment of clarity, knowing that our world will end, but that the present instant can never be erased. How precious is each moment spent on this glorious planet, part of the grandiose fire of life, this mysterious chain reaction that may be unique in the entire universe!

Occurring in a year, a century, or perhaps never, the possibility of such an encounter of massive celestial bodies should, in all cases, instill in our minds a greater appreciation for the bliss of being, here, today, as tomorrow may never come for us. Keeping the end always in sight, we shall live the present to the fullest, not focusing ourselves on the vanity of a legacy, our own or the legacy of our civilization, as every single trace we left upon the face of the earth shall one day be erased, but our accomplishments can never be undone. They are what will remain when everything else is no more. The towers of stone and iron surrounding us, painstakingly formed from the body of the earth, just like the most ancient and the sturdiest living pillars of wood of our forest, shall become dust scattered by the winds, or



Figure 12.2: *A Merger Between Galaxies* (NGC 2207, taken by NASA).

engulfed by the ground. We may picture this downfall, which may be sudden, even caused by the hands of our brethren and descendants wielding weapons of a formidable destructive power, or may perhaps be slow, the result of a natural erosion, the patient work of the skies, the passing of time. Contemplating the pale complexion of the luminary of the night, we may consider how it slowly escapes the attraction of the earth, distancing itself from our world. Watching the incomparable brilliance of the sun, we may remember that its glow is now brighter than it was to our most distant fathers, and that with each day that passes, its furious radiance grows, assailing the earth with an increasingly violent flood of fire. It is for now wholeheartedly welcomed by the living, fostering a healthy growth of the tree of life, but this source of its existence may one day be the cause of its death, as the earth will be scorched by this gigantic spark flaring in the darkness of the cosmos, like a flash consuming its substance before fading away, leaving only a pile of ashes behind.

When the star of life will begin to die of old age, our galaxy itself shall nonetheless also meet another, bearing the name of Andromeda. Visible with the naked eye if we succeed in escaping the blinding glow of our world, and close to the milky trail of our galaxy, let us behold this distant coalition of myriads of stars like our sun. As numerous as the grains of sand on an entire shore, these stars shall nevertheless probably never collide with one another, due to the

incredibly large distance separating them.² The earth shall nonetheless one day dance with them, being taken away from its course around the sun, balanced as a snowflake in the middle of a blizzard. This little cloud of light in the darkness of the cosmos is getting closer and closer to our galaxy, to our planet.³ May we welcome this dance that may be witnessed by our distant progeny, who may even find in this encounter a new home, a new earth, allowing them to escape the probable doom of our planet. Gazing at this luminous spiral, we may see in it a glimpse of the future of the earth and life.

The future of our planet may nonetheless also be seen upon its surface, here and now. Feeling our bones and touching our own skin, we may remember that we are not merely living upon the face of the earth. We are in fact the earth itself! The fire of life animating our bodies did not fundamentally transform our material nature. We are water, minerals, and metals, just like what lies beneath our feet. We are carbon and oxygen, just like the air enshrouding the planet. The fate of the bulk of the earth may already be sealed by the grip the daystar holds upon it, but looking at the accomplishments of the last generations, how they finally discovered the way to escape the smothering embrace of the core of the planet to wander throughout the depths of space, away from this sphere out of which we were born, we may imagine what those succeeding us will one day achieve. They may find the strength and resources to liberate mankind from the inevitable death of its star. Seeds of life may one day be planted upon distant planets, and the offshoots of the human race may witness the end of the earth from another world, honoring the conclusion of the first home of their lineage. Profoundly grateful for what this earth has offered us, we may thus also turn our hopeful eyes toward the starry sky, seeing in the milky trail of our galaxy what will perhaps be the future home of our children, another orb of stellar dust majestically shaped by the hands of the cosmos, providing what they will need to continue the glorious story we are writing right now.

²The nearest star to our planet, Proxima Centauri, is about 4.2 light-years away, but stars can be separated from others by distances of thousands of light-years. This 4.2 light-years represents more than 40 trillion kilometers, about 268,770 times the distance between the earth and the sun.

³The Andromeda Galaxy is approximately 2.5 million light-years away from our planet, which corresponds to 23.7 million trillion kilometers. The galactic collision between the Milky Way and the Andromeda Galaxy should occur in about 4.5 billion years. For more information concerning the simulation of this collision, see: Cox, T. J. et al. "The collision between the Milky Way and Andromeda." *Monthly Notices of the Royal Astronomical Society*, Volume 386, Issue 1, 1 May 2008. Pages 461-474.

Part II

The Earth Within Us: The Paths of the Elements

The story of the earth is a fascinating one. Unfolded extremely slowly, spanning eons, it nonetheless can be recounted in a few words, as its greatness does not lie in a convoluted plot, nor in a profusion of distinct events and things, but rather in the sheer scale upon which it takes place, considerably extended through space as well as through time. This story unfolds as an astronomical amount of particles and waves forming a gigantic and tempestuous mass, but one that appears to be fathomable with a very limited number of concepts by our minds, according to our remarkably incomplete knowledge of it. The heavens and the earth are absolutely immense, but the mind may nonetheless one day encompass their nature. Our vision of the past of the planet remains patchy, and the one we have of its future is a mere dream, but its present, the continuous writing of this story, like a stylus upon a block of wax, is far from a linear sequence of events. Reflecting the spherical nature of most heavenly bodies, the activity of the earth is a complex mechanism made of intricately interlaced cogs and wheels, continuously in motion. The substance of our planet finds itself caught in a permanent, circular flow. Matter is taken from the brazier of the mantle to the surface. It rolls upon the ground and then is picked up by the living, becoming part of them. It is breathed out of the lungs of men and beasts alike, joining the legions of the winds, before being thrown back onto the ground or into the seas. Earthly matter thus follows an almost infinite series of circular paths, piercing through the depths, passing through the heights, forming the coat of our planet, woven with air, light, water, and dust. The second part of this work will be devoted to the exploration of these paths, not simply to increase our familiarity with the nature of the earth, but foremost because these paths pass through us. The very matter of which we are made is indeed earth itself, and thus, before and after it formed our flesh and bones, it circled the greater earth, the realms linked with our world, the ground and the seas, life, and the air.

The substance of the earth is nonetheless far from being uniform. It displays a great variety of elements, arrayed in an astonishing number of configurations, and paired, according to various combinations. Each one of them possesses unique properties, defining the ways in which it interacts with the rest of the earth and the skies. The properties of each element are in turn derived from its components, as each atom representing this element is itself made of more elementary particles, a nucleus formed of protons and neutrons, surrounded by a cloud of electrons, that is, three different

expressions of matter, exhibiting different patterns of attraction and repulsion, kept in a more or less precarious equilibrium by the subtle interplay of some of the most fundamental forces of nature. To understand the palette of elements wherewith the earth and life are drawn, one must first become familiar with their uniqueness, what distinguishes them from others. The simplest and first of them all is hydrogen, the flame of the sun, its incandescent essence, composed of a single proton surrounded by a lone electron. Having opposite charges, they are attracted by one another, but the very fabric of the universe prevents their union, leaving them bound to one another to form an atom, but keeping the two at bay. This is due to the fact that uncertainty appears to rule the universe, and if too close, the two particles would threaten it, as their location would be known, something that would demand a considerable price to pay, in the form of a great amount of energy, an extremely strong impulse balancing one certainty with an equal uncertainty affecting another property.¹ This fundamental law of the creation is one of the keys “explaining,” in lack of a more appropriate word, the nature of matter. Requiring a tremendous force to be overcome, the barrier between the electrons and the nucleus of atoms is almost exclusively crossed inside the blaze of incandescent stars, where the immense pressure and inconceivable heat allows the addition of protons and neutrons to the core of the simplest of all atoms, transmuting it into new elements, increasingly heavier as the star ages and consumes its own substance. Another mysterious rule, an arcane law of the universe, also demands that no two identical particles be found on the same orbital around the core of an atom, orbitals that are themselves discontinuous, forming spherical layers that represent energy levels.² The heavier the element, the more complex the core and

¹This phenomenon is known as Heisenberg’s uncertainty principle. It states that certain pairs of physical properties, such as position and momentum, cannot be known with arbitrary precision at the same time. The mathematical formula for this would be: $\Delta x \Delta p \geq \hbar/2$. This applies to all particles, and it appears to be one of the most fundamental “laws” of our universe. It arises in the mathematical formulation of quantum mechanics, as an inviolable principle, but the physical implications of this principle are still the subject of intense debates by philosophers of science and physicists. (For more detailed information, such as the mathematical origin of this principle, see: Shankar, R. *Principles of Quantum Mechanics*. 2nd ed., Springer, 1994. Page 237; For the first publication of this principle, see: Heisenberg, Werner. “Über den anschaulichen Inhalt der quantentheoretischen Kinematik und Mechanik.” *Zeitschrift für Physik*, vol. 43, no. 3-4, 1927. Pages 172-198).

²This is known as Pauli’s exclusion principle. It states that no two identical fermions, that is, particles with half-integer spin, like electrons, protons, and

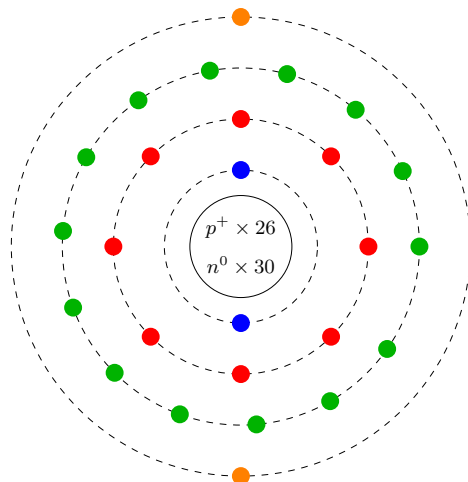


Figure 1: *Representation of an Iron atom.* (p^+ : number of protons; n^0 : number of neutrons; The colored dots represent the electrons)

the more numerous the layers where electrons are present. This arrangement of electrons, attracting or repelling the charged matter surrounding it, largely defines the way it will form bonds with other atoms and interact with light, and this, not only through a game of numbers, but also through their geometry. Having been thus named because man lacked the means until modern times to separate the particles forming them, atoms, the “indivisible” things, they form weaker bonds with others to form molecules, and these can in turn be assembled into complex compounds, without any rigid limit to their size. The earth itself represents a gigantic collection of such elements and compounds, and so do we.

The peculiarities of each element, such as its mass or the facility with which it can join itself with others, define a large part of its destiny. They trace the broad lines of the path it will follow as part of the greater earth, including life and the lower heavens. Some

neutrons, can occupy the same quantum state simultaneously. The organisation of electrons into layers in atoms emerges as a direct consequence of this principle. For more detailed information, such as the mathematical origin of this principle, see: Griffiths, David J. *Introduction to Quantum Mechanics*. 2nd ed., Pearson Prentice Hall, 2005. Page 179; For the first publication of this principle, see: Pauli, Wolfgang. “Über den Zusammenhang des Abschlusses der Elektronengruppen im Atom mit der Komplexstruktur der Spektren.” *Zeitschrift für Physik*, vol. 31, no. 1, 1925. Pages 765–783).

of them, like iron, are so heavy that the path they are destined to take will lead them to the core of our planet, circling the depths, but occasionally, a fortunate current may bring it to the surface, encased in rock. Its course would normally prevent it from rising above the surface, due to its remarkable heaviness, but the paths of the elements are often full of surprises, and thus, as life grew upon the earth, it began to take bits of this metal into the air, even soaring in the highest sky, riding on the wings of the lords of the upper realm, before returning into the tenebrous depths. Life retraced these paths as it learned to exploit the riches of the earth, and this is why many of them now pass through us, making us who we are now, whereas we remain utterly powerless to durably affect their nature. They bear no traces of their passage inside us, and will not remember their existence among the living. Born in the heart of a dying star, later forming the mantle of our planet, the earthly elements now impassively circulate between the earth and the air, and they will continue until one fateful day, when the earth will itself vanish, destroying their well-trodden paths, scattering them throughout the cosmos, but nonetheless leaving them perfectly intact.

The elements will remember nothing of their transitory belonging to life, but we, who are made of them, paradoxically can now keep the paths they took in the foreground of our minds. This gargantuan pile of well-ordered atoms we form can envision their origin and their destiny, and growing fully aware of the miraculous nature of this arcane ability, we shall exploit it to the fullest. The contemplation of the paths of the elements passing through our flesh can show us what we are, where we come from, and where we shall go. It can bring us closer to the earth itself, by showing us that we are only a voluminous mass of such elements, just remarkably cleverly arrayed, not through the will of our parents or any other creature, but rather through the astonishingly fortunate laws ruling the fabric of the space and time we occupy. The observation of each loop formed by an element passing through us should convince us of the arbitrariness of seeing ourselves as separate from the rest of our beloved planet. The earth is full of lessons we can learn, but the greatest of them all may be the simple fact that our whole being is merely earth, and that we shall cherish these instants when we are offered the chance of being a part of the earth that is able to behold and fathom the beauty of this mysterious realm.

The exploration of the paths taken by a selection of elements may now begin. These were primarily chosen due to the place they

occupy within our bodies, each one of them playing an inconspicuous part in our lives.³ The absence of a single one of them from our flesh would result in an almost immediate death, even though most would be unaware of the function of most of them. May this brief voyage through these paths cause us to enter into a deeper communion with our environment, to feel that we are part of our environment and not simply see ourselves as superior creatures inhabiting a realm meant to be exploited to our benefit. The first part will concern the paths of heavier elements, mainly passing through the earth and through life, while the second one will examine the lighter elements that can be elevated above our world, occupying the air enfolding the surface of our planet.

³The composition of the body by chemical elements is as follows: Oxygen 65%; Carbon 18%; Hydrogen 10%; Nitrogen 3%; Calcium 1.6%; Phosphorus 1.2%; Potassium 0.2%; Potassium 0.2%; Sulfur 0.2%; Chlorine 0.2%; Sodium 0.1%; Magnesium 0.05%; Iron <0.05%; Cobalt <0.05%; Copper <0.05%; Zinc <0.05%; Iodine <0.05%; Selenium <0.05%; Fluorine <0.05%. From: Chang, Raymond. *Chemistry*. 9th ed., McGraw-Hill, 2007. Page 49.

The Earth Within Us: The Paths of the Elements

Chapter 1

The Earth Reaching Life

Every atom, every piece of matter endowed with a mass, irresistibly feels compelled to coalesce with others, submitting to the gravest union. This is why the most massive elements are mostly present at the center of the earth, surrounded by layers upon layers of increasingly lighter ones, all ordered by the fundamental force of attraction. The bustling of the planet nonetheless perturbs this order. Chaos also rules this great realm, leading to the emergence of the paths of the elements, loops piercing through the ground and the seas, life and the air. The weight of these elements, determined by their complexity, the number of particles composing them, nonetheless creates natural boundaries. For many of them, the only way to rise above the rocky face of the planet will be to be lifted by a living creature, and the ethereal realm above it will durably remain out of their reach. We will now examine some of these elements, relatively heavy ones, with us relying on their nature to power the machinery of our life, and them depending on us to see the path they take make a detour into the middle realm, caught between earth and sky. The first section will nonetheless not concern any element in particular, but rather describe in broad strokes the paths of the rocks, in general, as the greatest cyclic path of them all, laying the groundwork for the exploration of individual elements.

Temporarily leaving out the heavens, the intangible vapors that will be subsequently discussed, to focus upon the solids and liquids found down below, here is a direct dialogue between the earth and life, a one-to-one encounter that should lead to a personal experience.

1.1 Rock

Fast-paced is the life of a man when set against the seemingly eternal nature of the earth. A lifespan may not be enough for him to witness any visible transformation of its surface. To him, it appears as death itself, the realm forming the ground where creatures are engulfed when the fire of life ineluctably departs from them, as imperceptible as its pulse may be, and as invisible as its movements may be, too slow for his impatient senses. Seen on the scale of the planet itself, the earth is nonetheless teeming with activity. It is animated by a pulse, beating deep under its hardened skin, and made of granite and basalt. It breathes, and its crimson blood flows. We merely need to pay the slightest attention to it to begin to unveil its nature, and to feel its rhythm.

The blazing flesh of our beloved planet is composed of a wide array of elements, almost unceasingly reacting with each other, forming various substances as they endure unbearable heat and tremendous pressure. Some of these elements follow a unique course, taken on a perpetual journey guiding them from the abyss of the ground to the peaks of the sky, but a large part of them are durably bound together, sharing a common destiny, bearing the simple name of “rocks.” The greatest and almost all-encompassing of all cycles of the earth, the long voyage of rocks represents the bulk of the activity of our planet, and the traces of this course, often overlooked, are nonetheless ubiquitous around us.

The rocky wheel of the earth, unceasingly in motion, has no beginning nor end. It is a continuum, and thus any part of it is an appropriate starting point for the investigation of its course, but perhaps the most natural is to simply take the first step where we now stand. Uncovering the rocky ground beneath the sooty ashes of life—the dark soil out of which the grasses and trees grow, we may attempt to assess its nature, its place in the great revolution of the wheel of the terrestrial rocks. Touching the face of the earth with our hand, feeling its texture, watching its asperities, we are deciphering the great book of the earth, unearthing the memory of the planet, as each piece of rock littering the ground bears a meaningful story within itself, waiting to be recounted. It shares with us the tale of its long journey, having taken it from the underworld blaze, the turbulent torrents of magma, onto the quieter surface, gently caressed by the winds and the rains, flooded with the celestial brilliance. Let



Figure 1.1: *A Volcanic Eruption, New Zealand.*

us now allow it to speak to us, telling us of its incredible adventures, those already experienced as well as those to come.

Every piece of rock now present around us, including the infinitely wide stone pillars supporting our presence, what we call “continents,” forming the foundation whereon our world stands, once emerged from the depths of the blazing mantle of our planet. Each took unique routes and encountered different predicaments, but all are equally ruled by the great ordering of all earthly matter, pushing the lighter chunks upwards, away from the heavier, implying that their course is largely determined by their nature, the palette of elements composing them. If they are in our vicinity on this very day, lying upon the surface separating earth from sky, our world, it is probably because they are lighter than those found deeper below, even though there are many exceptions. This, however, is not their final destination. Beholding the thick crust of our planet, the deep valleys and wide canyons, we are witnesses of the patient labor of the winds and the rains, ethereal forces that nonetheless are able, when offered ample time to do so, to carve the hard skin of the planet, to erode the most massive boulders, and reduce entire mountains to a fine dust. Carried by the rain and rivers, this stone powder is then poured into the ocean, becoming sediment piled up on its floor, or absorbed by the living. Compressed by the phenomenal weight of

the waters and the new layers continuously added upon it, these sediments are unhurriedly transformed. The space between each grain of dust is slowly reduced to naught, and they are in due time fused, ceasing to be a mere accumulation of single specks of dust to become rock, like sandstone or limestone. These may then subsequently be exposed to the air if the ocean recedes, like the rocks around us now, or they may continue to support other layers on top of them, bearing an increasingly higher pressure, altering them further.

As gigantic plates, part of the earth's crust, slowly move upon its surface, chunks from them are plunged back into the underworld. There, the compact dust turned into stone, and the solidified blood of the earth, are kneaded like a piece of dough by the powerful hands of the earth. Denied a return to a molten state, simply crushed and warmed in the planetary mortar, the nature of these rocks finds itself profoundly transformed. Bonds are unraveled on the scale of their fundamental elements, while others are allowed to be woven. A spectacular and yet unseen ballet of colors and textures unfolds far beneath the world of man, far away from his prying eyes.¹ This is how and where the most exquisite products of the earth are formed. They are the diamonds, rubies, and sapphires born amid darkness and fire.² They are the slabs of marble adorning the most luxurious palaces patiently crafted by the strength of the planet.³ Letting our dazzled eyes feast upon the beauty of the magnificent jewels born out of the lower Tenebrae, we may imagine the day of their appearance, picturing the astonishing force that turned a palette of haphazardly scattered particles into these superb creations. These, however, shall one day be returned to their source. These artworks shall one day be pulverized, thrown back into the earthly crucible, offered the chance of a new existence, metamorphosed into something new.

Guided by the whims of fate, the course of some rocks brings them deeper into the infernal entrails, into the blazing mantle whose

¹The rocks thus transformed are the so-called "metamorphic rocks." For more information concerning metamorphism, see: Grotzinger, John, and Thomas H. Jordan. *Understanding Earth*. 5th ed., W. H. Freeman, 2007. Page 131-149.

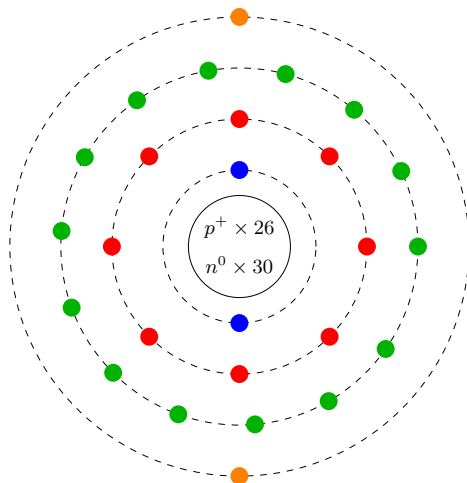
²Rubies, for example, are made of aluminium oxide with chromium, $\text{Al}_2\text{O}_3\text{:Cr}$. Sapphires are composed of the same aluminium oxide, but with trace amounts of elements such as iron, titanium, cobalt, lead, chromium, vanadium, magnesium, boron, and silicon. Emeralds are made of beryl ($\text{Be}_3\text{Al}_2(\text{SiO}_3)_6$), given its green tint by trace amounts of chromium or sometimes vanadium.

³Marble is a metamorphic rock that originates from limestone. Under high heat and pressure, the calcite crystals in limestone recrystallize and form marble. The inclusion of other minerals gives it its characteristic patterns and colors.

Rock

incandescence soon causes them to melt and become one with it. The palette of elements composing them is then mingled by the currents of magma, calmly running around the iron core of the planet, until an opportunity finally presents itself, when a wound appears on the skin of the earth, letting the flaming blood gush out onto the surface, encountering the freshness of the air, running upon the earth as it immediately experiences the smothering jealousy of the core, wanting to take it back to the depths, causing it to flow toward the lowest ground, deep into the ocean. The heavenly forces nonetheless calmly thwart this naive attempt to escape their grip, as they swiftly rob this blazing liquid of its heat, rendering it increasingly viscous, before it finally loses its red glow and becomes solid rock, marked by the air, pervaded by minute holes left by the presence of gases escaping to the heights, deserting the stone before it is too late to side with the winner of this duel. A new layer is thus unhastily poured upon the ground. Many of the islands adorning our planet emerged from the waters during similar events, and the holes in these rocks are testimonies to their volcanic origin. Holding samples of such rocks, we touch the clotted blood of the earth, the flesh of the planet that ran out of a wound upon its face, rapidly cooled down by the air or water. It is an offering of the abysses to our world, and to life, as the myriad of elements contained in such rocks are essential components of our bodies. We are fed by the blood of the earth, and more than this, we are partly made of it. It flows through us, at this very moment.

The cold blood of the planet now exposed to the caprices of the heavens is patiently worn down. Speck by speck, it is carried into the soil, poured into lakes, rivers, and seas, allowing them to be utilized by life itself. Metals and minerals thus continue their endless journey, taking them from the deepest underworld to the highest branches of the tree of life, even possibly reaching the heights of the sky when carried there by the living, turned toward the farthest heavens. They subsequently come back to their source, to the place of their origin, with all this cycle majestically set in motion by the commotion reigning under the crust, the heat causing its substance to unceasingly flow. Pondering on the scale of this grand wheel whereon our life depends, in time and in space, too great for us to perceive its turning, we may nonetheless appreciate the role it plays in our humble existence, and in the fashioning of our cruel and yet beautiful world.



1.2 Iron

Forged in the heart of a star, whose ashes were gathered to form the sun and the earth, iron is one of the most common elements of our planet.⁴ Most of it sank toward its center during its infancy, when the great ordering of all earthly matter caused the arrangement of its various layers, now forming the bulk of its solid core, with currents of the molten form of this metal circling it. These blazing abysses obstinately remain out of the reach of our tools of investigation, but venturing into the farthest north or the deepest south of the planet, we may with our naked eyes witness conspicuous signs of this imposing presence, as these rivers of iron are the hidden source out of which an invisible force field deflecting the fiercest envoys of the sun is deployed. It is a shield upon which strong rays from the daystar collide in a colorful ballet in the highest sky, a display known under the name of auroras. Beholding such a marvel of nature, what

⁴One estimation of the composition of the earth in terms of chemical elements is as follows: Oxygen 32.4%; Iron 28.2%; Silicon 17.2%; Magnesium 15.9%; Aluminium 1.5%; Calcium 1.6%; Nitrogen 1.6%; Sulfur 0.7%; Sodium 0.2%. Percentages taken from: Allègre, Claude J., Jean-Paul Poirier, Eric Humler, and A. W. Hofmann. "The Chemical Composition of the Earth." *Earth and Planetary Science Letters*, vol. 134, no. 3-4, Sept. 1995, Pages 515-526.; The composition of the crust of the earth is as follows: Oxygen 45.5%; Silicon 27.2%; Aluminium 8.3%; Iron 6.2%; Calcium 4.7%; Magnesium 2.8%; Others 5.3%. These percentages were taken from: Chang, Raymond. *Chemistry*. 9th ed., McGraw-Hill, 2007. Page 49.

we see is the work of the iron core under our feet, a beacon of the heart of our planet.

The great ordering of all pieces of earthly matter according to the masses of their elements is nonetheless far from absolute. Some succeed, for some time at least, in escaping the invisible hands of gravity, usurping a place in this natural hierarchy. The common and yet valuable metal is thus sporadically brought near the surface by the blazing currents running through the underworld. Found together with a great variety of minerals and other elements in the rocky crust, the heavenly forces worked to grind them down with winds, rain, or hail, scattering their ingredients over the land and into the rivers and the seas. As a result, the soil we tread contains traces of the star-born metal, in just enough quantities for it to be exploited by the middle realm caught between earth and sky. The emerald beings rising from this soil, meticulously harvesting the luminous gifts of our life-giving star, are more skilled than any of us in this respect, as they have the means of collecting this precious metal, discerning its presence among various other substances. They extract it and carry it above the surface, making it part of their stems, their leaves, their seeds, or their fruits. To do so, they employ sophisticated techniques, an ancient artistry of life, some even altering the soil around their roots to change the form taken by the iron present in it, thereby facilitating such extraction.⁵ Through their discreet labor, the core of the earth is brought closer to the sky, closer to the daystar, direct offspring of the brilliant celestial body that once forged this versatile metal in its blazing entrails. This extraction is nonetheless far from being selfless, as iron plays a crucial role in various parts of their bodies, such as the transport of the energy animating them, or the synthesis of the green substance giving them their characteristic hue, which is used for the harnessing of the sun's brilliance.⁶ Carefully touching the green flesh of a

⁵There are two major strategies employed by different branches of light-workers for the uptake of iron. The first, employed by non-grasses, is based on the acidification of the soil surrounding the plant's roots (the rhizosphere) by the excretion of protons and the reduction of iron ions. The second, used by grasses, is based on the release in the soil of certain substances (phytosiderophores), having the peculiarity of being able to strongly bind themselves to iron ions. Acting like chemical claws (chelators), these substances are then retrieved by the grasses, together with the iron attached to them. (For more detail, see: Martín-Barranco, Amanda et al. "A quick journey into the diversity of iron uptake strategies in photosynthetic organisms." *Plant signaling and behavior* vol. 16, 2021.

⁶Better known as "chlorophyll," from the Greek words "χλωρός" (khloros, meaning "pale green") and "φύλλον" (phyllon, meaning "leaf").



Figure 1.2: *Iron Ore*

plant, let us be mindful of the presence of the heavy substance of the core of our planet in these delicate living things, picturing it being carried around them, used as an essential element of its incredibly sophisticated machinery. Part of this iron shall be returned to the ground when these stems and leaves wither and crumble into dust, but for some of these emerald beings, those catching the attention of living beings, animals in particular, the metal in their midst may then continue its great circumambulations above the surface of the earth.

Seizing a fruit or a vegetable from our pantry, laying it in front of us, exposed to our gaze, we may unhurriedly feel its texture. What we touch contains a minute but nonetheless extremely essential quantity of iron. When we let it cross the threshold of our body, entering our mouth and sliding into our hungry belly, we make this metal ours. It becomes part of us, a crucial element necessary for the fire of life to continue consuming us. Perhaps the most important role played by iron in our lives is the central place it occupies in the red cells flowing in our veins, the essence of our blood.⁷ In each one of them, there are millions of identical molecules,⁸ whose

⁷These cells are better known under the name of “red blood cells”, or “erythrocytes.”

⁸This compound is the hemoglobin molecule, a very large protein, composed

Iron

sole purpose is to carry oxygen, the energetic wealth of the heavens absorbed by our lungs, to every cell of our bodies. This substance contains exactly four atoms of iron, endowed with a particular affinity with the treasured gift of the heavens, binding to it naturally and allowing it to be securely transported. With every breath we take, we welcome the legacy of the emerald beings stored in the heavenly storehouse into our chest, but we also employ the other gift of these weavers of the sunlight, as it is the iron they mined from the soil that helps us to carry it to each corner of our body. Deeply inhaling and exhaling, feeling the red fluid of life flowing throughout our torso and our limbs, we shall reflect on the invaluable presence of the star-forged metal, and be grateful for its contribution to our humble existence, as it offers us the chance to harness the force stored in the immensity of the sky.

Slightly puncturing our bodily envelope, letting a drop of the red liquid escape the confines of our skin, its vivid tint should attract our eyes. This color, inspiring dread in our hearts as the result of one of our most deeply entrenched instincts, offers a high contrast with the rest of our body. This bright shade is a sign of the presence of iron itself, the same as the rusty objects neglected in the world of man, products of an encounter between the essence of the earth and the essence of the air. Rust and blood both represent a reunion of iron and oxygen, a marriage of earth and sky, with the latter sustaining life. The heavy heart of the planet thus beats through our veins, flowing together with the winds of the heavens. We may pay attention to this aspect of our body, as we now focus our attention on our breathing and the beating of our heart, the rhythms of our lives, the pace of our existence. Their activity, echoing in unison, shall nonetheless one day cease, marking the conclusion of our days upon this earth. When this fateful moment occurs, our blood shall return whence it came, and the iron it contains shall seep back into the depths, carried by the rains. Transiently raised upon the surface to serve life, it then once again becomes earth, keeping no memories of this existence to which it belonged, just as it forgot the day of its birth in the deepest entrails of an aging star. Let us picture the tortuous course of these minuscule elements, the great journey they undertook before becoming part of us, and let us try to imagine

of close to seven thousand atoms, among which are four atoms of iron that can “carry” oxygen throughout the body. A hemoglobin molecule contains a total of 4664 hydrogen atoms, 2952 carbon atoms, 832 oxygen atoms, 812 nitrogen atoms, 8 sulfur atoms, and 4 iron atoms, resulting in a total of 6,772 atoms.

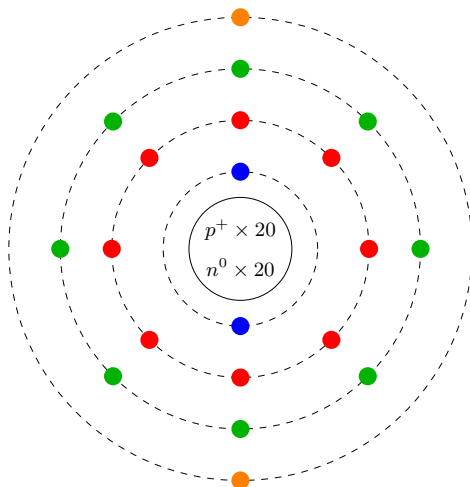
where the morrow will take them.

The emergence of life thus steered the course of iron into a new direction, above the surface of the earth, but subsequently, as man grew in intelligence and extended his appropriation of the lower realm, he also further altered this course, causing the metal to find a place of choice within his world. Having discovered that the red dust in the ground would form solid pieces of shiny metal after having been thrown into a blazing furnace and allowed to cool down, but remaining malleable while sufficiently hot, he soon engaged in a frenzied search for this bloodstained treasure of the earth. Burning entire forests to feed the furnaces required for the smelting of iron, digging deep veins in the ground to access this increasingly hidden resource, man raced against his peers to forge a new world with this mystifying substance. The blade of the earth was pulled out of the rocky crust of the planet, and swiftly used to spill rivers of blood, for food, for power, or for glory. Incredibly hard and resistant, tools of iron profoundly changed the world of our species. Taking into our hands one object made of such material, we may feel its cold touch and its resistance to the force of our fingers. What have we made of this immense treasure robbed from the ground? What shall we do with this booty extracted out of the coffers of the planet?

Omnipresent in our world due to its durability, the abundant metal is nonetheless far from immutable. The treasure of the earth, if left in the open, is indeed easily degraded by its surroundings. It, in particular, continuously interacts with the gift of the heavens to the animals, oxygen. Left exposed to the elements, iron soon loses the glossy appearance imparted to it by the hand of man, and is once again clad with a flaky coat of red. The solid mass forged in the furnace is slowly eaten by the work of time and the invisible hands of the winds. It crumbles into a rusty dust, returning to the ground, the place of its origin. What man appropriates and elevates above the earth is ineluctably taken back to it, no matter his efforts, and regardless of his unequaled obstinacy. The course of iron always comes full circle, returning to the depths, but it will one day once again pass through life and our world. Looking at the rusty objects around us, we may see in them parts of the bodies of our distant descendants, or pieces of future creations of their minds, things yet to be invented. From the core of the earth to the most distant object thrown into the depths of space by mankind, iron lies at the center of our world. May we fully appreciate the various roles it assumes in it, and perceive the true worth of this substance, part of us and

Iron

of our life.



1.3 Calcium

The earth is like an immense cauldron, a great gathering of elements stirred up by the hands of the cosmos. Its crust appears to us as mere “rock,” familiar to us for its rigidity and texture, but its incredible diversity often escapes us. Minerals come in various shapes and colors, with diverse properties, and each one of them is unique in its capacity to interact with other forms of matter. Learning to discern the ingredients of the ground whereon we stand may thus be an enlightening experience, not only shedding light upon the nature of our planet, but also on our own. Calcium is one of these minerals, omnipresent around us and within ourselves, and yet so often overlooked, so commonly ignored, left out of the range of our interests. It circles our world, coming from the infernal depths and rising up to the top of our skull, unceasingly passing through its different layers, and thus we may begin our examination of this element at different points on this course through the earth and life.

A way to enter into contact with calcium may be to roam a sandy shore, walking on the remains of countless living beings that have now returned to the ground. Their flesh has been consumed by other forms of life or simply decayed into dust dissolved in the ocean. All that now remains of them is their shell, what was their bodily envelope and their home, a hardened piece of dead matter shielding their life, a rampart against aggression. These shells are a subtle

Calcium

blend of earthly calcium with the carbon winds blowing throughout the heavens,⁹ a reunion of the strength of the earth with the strength of the sky, defending life. Caressing these elegantly crafted spirals, observing the sophistication of their structure, contrasting with their unyielding rigidity, we may behold with awe the miracle of life, able to craft such marvels, without any plan, without any will, using the wealth of the ground to create such works of art, legacy of these dwellers of the oceans, standing like monuments to their existence, as the rest of them have vanished into thin air. Eroded by the waves, crushed under the feet of oblivious men, these shells are nonetheless far from eternal. Turned into a fine powder by the sky or the living, they without respite continue their journey through the strata of nature.

The substance of seashells may then encounter acid rains, laden with corrosive substances, reacting with them, leading to the isolation of the calcium of these shells,¹⁰ allowing the calcium to be directly absorbed and used by plants and algae, the noble weavers of sunlight. The rest may run toward the seafloor, becoming sediment increasingly compressed by the mass of water above it, buried deeper and deeper. Given enough time, subject to enough force from the earth, it may then be turned into limestone,¹¹ returning to the depths of the earth before is one day be brought to the surface, part of a continent, ground of the world, continuing its long voyage. Looking for a piece of limestone, feeling its grainy texture on our finger, its weight, and observing its tint, which should remind us of the one observed in the seashells, let us imagine the long journey taken by these bits of calcium, compressed by the earth itself into this rock. Parts of it may have formed the bodies of ancient creatures that occupied the seas long before the foundation stone of our world was laid by the first men, and other parts may one day join the flesh of our distant descendants, who perhaps will have emancipated themselves from this planet, having discovered another hospitable celestial body.

When the forces of the sky once again liberate calcium from its prison of stone, letting it seep into the sooty soil, an aggregate of

⁹This compound is Calcium Carbonate: CaCO_3 .

¹⁰The calcium carbonate forming seashells reacts with the sulfuric acid (H_2SO_4) and nitric acid (HNO_3) contained in acid rains. This reaction dissolves the calcium carbonate, converting it into calcium ions (Ca^{2+}) and bicarbonate ions (HCO_3^-). The reaction formula is: $\text{CaCO}_3 + \text{H}^+ \rightarrow \text{Ca}^{2+} + \text{HCO}_3^-$.

¹¹Limestone is made of calcium carbonate, CaCO_3 .



Figure 1.3: *Calcium*.

decomposed cadavers of former living beings wherein the weavers of sunlight take root, it can once again rise up to become part of life, this time reaching up to the sky rather than occupying the shallows of the ocean. The inconspicuous element explores another path, becoming a stem or a leaf, a seed or a fruit. Seizing one of these masterworks of the weavers of light with our hand, taking a bite and masticating it thoroughly before swallowing it, mingling earth and sky for the benefit of life, the minute quantity of calcium it contains will be separated from the other elements bound to it by the acid of our stomach, slowly released into our digestive tract, before it finally enters our bloodstream, becoming part of us. In every part of our skeleton, specialized cells¹² make use of this calcium, interlacing it with phosphorus and other elements to form new bones or teeth. More than a mere scaffolding of our flesh, these bones are also reserves of calcium, a substance with many other uses by our bodies. If calcium is found to be lacking in our blood, our bodies then know when and how to break down these bones to tap into this precious reserve of the vital element, wisely sacrificing the frame to save the essence. Gnashing our teeth, feeling the hardness of our

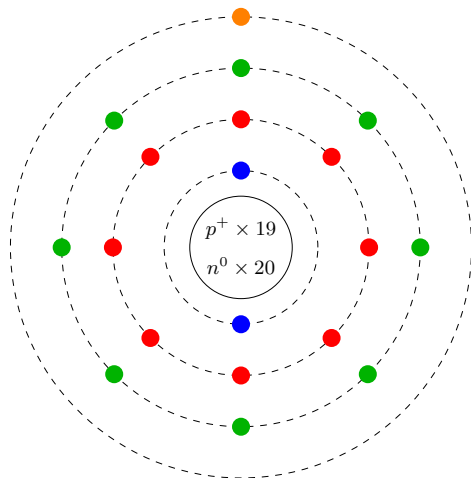
¹²These cells are known as osteoblasts, “cells that “germinate” bones” in Greek. For more information concerning this type of cell, see: Ross, Michael H., and Wojciech Pawlina. *Histology: A Text and Atlas*. 7th ed., Wolters Kluwer, 2015. N.p. (Chapter 8.1).

Calcium

bones, this is the strength of this element that allows us to proudly stand erect upon the face of the earth, resisting the downward pull of the iron core and its rocky vestment. Thanks to its force, we can appropriate the earth itself, employing tools with our hands, crushing flesh with our jaw, cutting skin with our teeth. From stone to plant to animals, this invaluable substance is now part of us. Let us feel its strength all around our skeleton, from the summit of our cranium to the tip of our toes. We are stone raised from the ground, pointing at the stars similar to the one that forged it. We are the shells of ancient marine creatures on the coast of a different world. We are the leaves of the oldest trees, trees that were once anchored into this ground. In a few years, when our hearts will stop beating, and our blood will run into the dark entrails of the earth, all that will remain of our cadavers will be these bones and teeth, in every way similar to the innumerable shells turned into sand by the winds and the waves. Where will our bones be then? Who will behold them with pity or curiosity, wondering about who we were? But even these bones shall once again continue the endless journey of the elements composing them, either returning to the ground as stone or to life as a part of a new being.

Calcium is nonetheless more than the scaffolding of creatures endowed with shells and bones. It also forms the major part of the scaffolding of many tangible parts of man's world. He has indeed learned to appropriate this substance, even long before he could identify it and uncover its link with his own body. All around us, at this very moment, every bit of cement and concrete used to construct the buildings, bridges, and roads of our world stands thanks to the properties of calcium, found in them. Limestone, containing this element, is one of the main ingredients of cement. It holds its various components together, just like it does in shells and bones. Man thus imitates life by his appropriation of this substance, following its lead. Placing one of our hands on a concrete wall, feeling it resist the push of our limb, we may experience the affinity between our skeleton and this invention of our brethren. Both are very similar, resting on the binding power of calcium, extracted from the ground, stone crushed into dust before it was either turned into life or a part of the frame of our world. This element is unique in its capacity to form strong bonds that remain largely unaffected by the dissolving power of water. It is not harmful to life, is remarkably stable, and is available in great abundance all over the globe. Watching high towers of concrete, tall ramparts bound by cement, what

we behold is the backbone of our world, the frame of our civilization. It is a skeleton very similar to ours, fashioned with the same substance, generously offered to us by the earth and continuously traveling through the realms of nature, passing through us just like it goes through our world. Let us feel this bond uniting us with these imposing structures, and the ground itself, whence their substance came.



1.4 Potassium

Born in the bustling inferno deep under our feet, fashioned with fire and pressure, minerals like feldspar and mica travel through the mantle and occasionally reach the surface, encountering the air, befriending the breeze and the drizzle from the sky. These fortunate meetings between the earthly and the heavenly often result in the creation of something borrowing the qualities of both realms. Here, these rocks are patiently eroded by the forces from above, their solid nature compromised as they are turned into a fine dust, able to be briefly elevated by the winds into the air, but mostly carried by the rains, into the soil, into the rivers, ultimately running toward the ocean. Released by this celestial intervention, potassium then pervades life, serving a wide variety of essential functions. It is commonly known by the name of potassium. Some of it will take the shortest route soon after its liberation from the rock, plunging into the great expanse of water, swimming to the seafloor, letting itself be buried under layers upon layers of various sediment, before it is once again brought down to the crucible of the underworld, thrown into the terrestrial cauldron with other elements, to finally once again be turned into a new kind of rock, that shall one day reach back to the surface, continuing its long, circular journey. The rest of it will nonetheless take a more sinuous course, not only roaming the earth, but letting itself become part of life and man's world.

Released from feldspar or other rocks by the work of the heav-

ens, potassium is immediately soluble in water.¹³ Penetrating into the soil in which the light-workers of the land take root, as they build up life from the essence of the earth and the sky, this element renders it more fertile, causing life to thrive in the land it penetrates. Immediately absorbed by these roots, as it is not bound to any other substance that may prevent its use, it patiently climbs the ladder of life, rising above the surface by following the veins of the emerald beings, letting itself be touched by the brilliance of the daystar, similar to the one that forged this element long before the birth of our planet. Potassium is nonetheless far from a useless addition to the wide palette of substances found in these living things. It promotes the growth of roots and fortifies the plants as they resist drought and disease. It plays a crucial role in their capacity to balance the levels of various substances present in their bodies, such as water or the carbon winds (CO_2). It also plays its part in the weaving of sunlight into life, and without it, we would thus be condemned to starve and return to the earth. Grabbing a piece of feldspar, attentively observing its structure, feeling its texture with our fingertips, we may picture the work performed by the heavens to weather this product of the depths of the earth, imagining the course that the potassium it contains shall one day take. It shall be turned into a fine dust dissolved in the rain or rivers. It shall creep into the body of a plant, and there, it will serve as a chemical balance, a judge or an overseer, determining whether the presence of other substances is wanted or resented, whether they should be welcomed or expelled from the green walls of the being wherein it performs its labor.¹⁴ Letting our hands pass upon the leaves of one of these weavers of light, we may reflect upon the role played by potassium within it. Mere dust from a rock is what allows this surprisingly complex piece of machinery of life to function, keeping a delicate equilibrium within its walls, maintaining a perfect balance. Without it, we would have nothing to sustain our bodies. The entire tree of life stands because of the role played by this element, and thus we may take a moment to pay homage to its priceless contribution, so often ignored by ungrateful men.

The balancing power of potassium is nonetheless not restricted to the light-workers. We, humans, also crave its inconspicuous force,

¹³It is dissolved in water as potassium ions (K^+).

¹⁴For more information concerning the role played by potassium in the human body, see: Da Silva, J. J. R. Frausto, and R. J. P. Williams. *The Biological Chemistry of the Elements: The Inorganic Chemistry of Life*. 2nd ed., Oxford University Press, 2001. Pages 223–241 (Part II.8).



Figure 1.4: *Potassium.*

and when we ingest their green flesh or the bloody flesh of animals, we absorb this element, only in minute amounts, but enough for its power to be revealed in our bodies. One of the key functions of the potassium found inside our bodily envelope is to control the contractions of our muscles, and especially the involuntary ones of the most vital of them all: our heart. Together with sodium and calcium,¹⁵ potassium is used to open and close the minuscule gates of our muscles, allowing them to contract and be relaxed. This capacity to balance the machinery of the living is paradoxically due to a fundamental imbalance in the very essence of these substances. These elements are indeed present in a form lacking electrons, transforming them into infinitely small positive charges, constantly attracted to substances with an opposite charge. Flowing like blood and water, these elements form electric currents, able to activate living switches omnipresent in the grandiose machinery of life. Feeling our own pulse, listening attentively to its regular beating that sets the

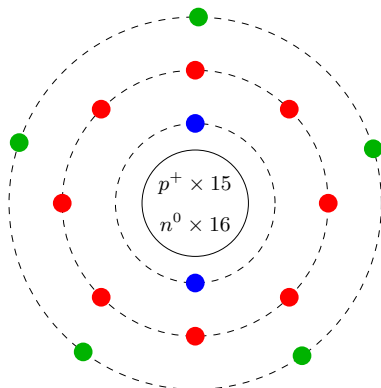
¹⁵The two elements are then found as ions. Sodium ions (Na^+) are used as a preliminary signal before the contraction, triggering the release of calcium ions (Ca^{2+}), which cause the contraction. When the calcium ions are removed, the muscle cell relaxes. For more information concerning the role played by calcium in the human body, see: Da Silva, J. J. R. Frausto, and R. J. P. Williams. *The Biological Chemistry of the Elements: The Inorganic Chemistry of Life*. 2nd ed., Oxford University Press, 2001. Pages 268–296 (Part II.10)

pace of our existence, we may picture the tiny fluxes of potassium running through each one of the myriad of muscle fibers of our heart, meticulously controlling the rhythm of its contractions according to the predicaments into which we are thrown, responding to the whole of the body as well as to our surroundings. This delicate balance, upon which our life depends, relies on these simple minerals offered to us by the earth, meticulously prepared by the transparent hands of the sky. Rocks like feldspar flow inside our muscles, animating our limbs by harnessing an electric force. How intricate is our body! How wise is life itself! It gathers the earth and the sky within this water-skin formed by our body, burning and consuming us, until the last day of our life above the ground, when the flows of charged minerals will be brought to a standstill; when the drumbeat resonating within our chest will fade into an eternal silence, and the wealth of the earth appropriated by our flesh will be returned whence it came, once again running into the depths. For now, however, let us be humbled by its work of alchemy, allowing us to experience the bliss of being, during the present instant.

The cyclic journey of potassium nonetheless sometimes takes a detour, placing it into the hands of man rather than inside his body. Having become aware of its remarkable properties after ages of ignorance of its nature, we now mine this mineral, directly from the belly of the planet, violently crushing the rocks containing it, replacing the work of the sky, too slow to our liking. Interlaced with other substances craved by the living, by the light-workers rooted in the ground in particular, the products of this pillaging of the ground become fertilizers, scattered upon our fields, feeding the growing plants that will feed our world after the next harvest, if the heavens are clement enough, offering their indispensable assent for the extension of our existence. Feasting upon these powdered rocks, as if it were the most exquisitely prepared delicacy, the emerald beings thrive, eating away the substance of the earth and the sky to allow the middle realm, life, to occupy the space between them, gloriously sprouting, extending its arms toward the life-giving daystar. This, in turn, considerably increases the resilience of our species. Thanks to our appropriation of this mineral, we stand upon the earth more securely than ever, enjoying a plentiful amount of food, key to the growth of our branch of life. Observing a well-stocked pantry, or visiting a busy marketplace, we may ponder the fact that most of what has been grown out of the earth to sustain our bodies has been fed with a selection of minerals mined in the ground, by our hands.

Potassium

Satiating our appetite with these bountiful fruits of the planet, products of our world, we may also reflect upon the role played by man's mastery of the earth in their cultivation. Our knowledge of the lower realm, and our willingness to exploit its riches, are what enable us to extend our days above the ground, before we inevitably end up as part of it. Paying homage to those who tirelessly labored to extract the mineral wealth of the earth so that it would serve our world, let us also recognize the planet as the source of our endurance, the spring of life itself.



1.5 Phosphorus

Life is a genuine miracle, the most improbable chain reaction, bewitching earthly matter and making it appear radically different from the rest of nature. It seemingly stands out from it because of the capacity of certain creatures to decide where they go and what they do, to exploit the resources surrounding them, and to reproduce and evolve as the turning of the heavenly wheels paces their existence. A fire consuming the earth and the air, this is what life is. We are not burned by this fire, but rather are this fire ourselves, propagating it by our instincts of love and lust, communicating this enthrallment to new parts of the earth, new parts of the dead realm, with each new generation. This fire is astonishingly complex, a remarkable assembly of innumerable elements perfectly interlocked with one another, a sophisticated ballet exhibiting such perfection that it may be hard to believe that it would not be the result of a precise intent, as mysterious and unfathomable as its source may be. Among these, phosphorus occupies a particular place. It indeed is a key element in vastly different parts of life, pervading most of our bodies. A gift, graciously offered by the earth itself in the form of phosphate¹⁶ rock brought near the surface by the torrents of magma underlying our world, this element must first be released from its prison of stone before it may be put to good use by the living. Faithful ally of life, and a great realm fostering its growth since its inception, the heavens take upon themselves this critical task. They meticulously break the minuscule but strong bonds uniting phos-

¹⁶The phosphorus found in rocks is almost exclusively in the form of phosphate ions (PO_4^{3-}).

Phosphorus

phate molecules to others, but they leave intact these compounds, and elemental phosphorus remains bound to different atoms of oxygen, wealth of the sky here imprisoned in the rocky body of the earth. These assemblies of minerals then run upon the face of the planet. They penetrate the soil, carried by the clear drops from above, envoys of the sky entering the ground without any impediment, and when they encounter the roots of the industrious laborers interlacing earth, light, and air to create life, the green fire clothing our planet, they are warmly welcomed by them, without the need to alter their nature, just as they are greeted with utmost pleasure by the myriad of minuscule beings inhabiting the ground, equally eager to use the strength of these unexpected guests.

Ascending to join life, above the earth, under the sky, the phosphate molecules are then manipulated, coupled with other substances, and assigned different roles in the great community formed by the weavers of sunlight hosting them. They first play a crucial part in the main molecule used to power the machinery of life,¹⁷ the substance carrying the energy used to transform other substances, to open or close chemical doorwaysthat pervade the body, to trigger the formation of new parts of living creatures, essentially the same force as the lightning bolts illuminating dark thunderous clouds or the one setting in motion the machines of our world.¹⁸ Through the agency of this substance holding a power of attraction and repulsion, flowing through each one of its veins, pervading its entirety, the fire of life continues its consumption of the earth and the air, sustaining and inflating the middle realm occupying the surface of our planet. It does so in the emerald beings fed by the radiance of the sun, but it also performs the same work of alchemy within us, as we ingest their fruits, their seeds, or their flesh, holding within themselves bits of the precious mineral. We cannot elevate it from the ground into our bodies ourselves, but these selfless creatures perform this work in our stead, letting us feed upon the fruits of their tiresome labor for the elevation of life. From the obscure depths of the earth, passing through the emerald weavers of light before becoming part of us, vessels of blood and water roaming the dry land, this phosphorus

¹⁷This molecule is adenosine triphosphate (ATP). Each day, our body makes use of a considerable amount of this molecule: “An average individual with a daily diet of 8000 kJ and a 30% efficiency of turning foodstuffs into chemical energy will synthesize (and hydrolyze) about 50 kg of ATP during a single day.” See: Wilkens, Stephan. “ATP Synthesis, Chemistry of”. *Wiley Encyclopedia of Chemical Biology*. Wiley, 2008.

¹⁸That is, the electro-magnetic force.



Figure 1.5: *Phosphorus*.

now pervades every part of our flesh. Taking a brief moment to feel our own blood flow, we may pay attention to these weathered pieces of the gray mineral, pieces that slowly climbed out of the ground to finally run through us right now. Every movement we make, every thought that arises from the inscrutable depths of our mind, and every memory recalled from the innermost layers of our psyche, occurs because of the presence of this particular mineral. Were it absent from the vast coalescence of stardust that formed our planet, we may not stand here now, and life itself probably never would have arisen.

Eating the succulent products of the light-workers particularly rich in phosphorus, like sunflower seeds, we let a part of the earth enter our body. We appropriate the force of this element for the building of our flesh and its animation. The role it plays within us is nonetheless far wider than the powering of the machinery we form. Phosphorus is not only the bearer of our strength, the light of our thought, it is also the wall of life, the bricks with which the enclosure formed by each one of our cells is built. Marrying an oily compound repelling water with a phosphate one attracting it, arrayed in two superposed layers,¹⁹ these walls allow the creation of

¹⁹These compounds are phospholipids. They are a kind of lipids whose molecule has a hydrophilic “head” containing a phosphate group and two hydrophobic “tails” formed from fatty acids. They can form bi-layers, acting like

Phosphorus

an equilibrium, a balance between attraction and repulsion, letting the cell absorb and reject, according to its needs. Furthermore, the same mineral treasure offered by the soil, together with calcium, also forms the bulk of our skeleton, frame of our body, the load-bearing walls hidden under our leathery skin, allowing us to resist the ubiquitous downward pull of the earth. Touching our skin, we enter into direct contact with these different sorts of walls, built with rock extracted by the forces of the sky from the earth. These living ramparts defend us from the assaults of the outside world, whether they come from men or nature itself. We wield this force of the lower realm to protect our existence. Let us dedicate a moment of the present day to reflect on what we owe to this phosphorus pervading us, seeing how we are the earth itself, a layer of matter moving above the rocky crust, not simply appropriating it, but integrally part of it.

Extremely versatile, exploited to the fullest by life, phosphorus is also a crucial element of its innermost essence. It indeed is found as a component of each one of the characters wherewith the book of life is written. It is part of the ink used to inscribe the lengthy list of signs defining each living creature, determining its development, part of its destiny.²⁰ Our existence is written with this mineral. The legacy of our forebears was carried by it, from the inception of life to the present day, in the very body reading these lines. But it is not only our story that is thus written in a phosphorus ink. The entire story of life is thus preserved, folded and concealed in the innermost sanctuary of each cell, in each living thing found in the air, on the ground, or in the seas. Taking a glance at the great variety of the branches of life found around us, we should see in them unique stories written with the rocky earth, turned to dust by the sky, transformed into a complex ink by life. Each feature that makes them who they are is defined with these grains born out of stone, itself begotten by a star. We remain ignorant of the origin of this formidable order and its purpose, if it has one, but it invites us to stand in awe of the incredibly improbable emergence

walls repelling water. Cell walls are formed with such structures. For more information, see: Nelson, David L., and Michael M. Cox. *Lehninger Principles of Biochemistry*. 4th ed., W. H. Freeman, 2004. Pages 369–420.

²⁰This long list of signs is the DNA molecule, an abbreviation of deoxyribonucleic acid. Information in this molecule is encoded using four nucleotides, representing the “characters” of this means of recording information: cytosine, guanine, adenine, and thymine. Human DNA contains around three billion such “characters.”

of such a perfection, such an amazing sophistication, even allowing us to reflect upon the role it plays in our being. When we mine the riches of the earth, piercing its body to extract them and offer them to the light-workers so that they would flourish and support the extension of our world, even sometimes wrecking the delicate balance of nature through an excessive intervention,²¹ we should be mindful of the path it will take, from the crust of the planet to each part of our body, before it returns to the ground after our death and is once again hardened into rock, continuing its endless voyage between earth and life.

²¹One of such excessive interventions of man is named eutrophication. It represents the phenomenon of an overabundance of nutrient in a body of water, often due to an overuse of fertilizers in nearby fields, which causes certain organisms to flourish in great numbers, typically algae, depleting the supply of oxygen in the water, decimating other species.

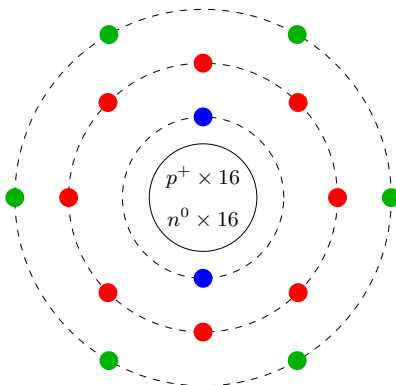
Chapter 2

The Earth Reaching the Sky

The path of some of the relatively heavy elements found on our planet stops at the extremities of our bodies. We are the crests of these paths, and once they depart from us, they return to the ground and the blazing depths of the mantle. The palette of elements comes with minute increments in size, their heaviness increasing only by the weight of a proton, neutron, and electron at a time. This is nonetheless sufficient to trace a clear frontier separating what now appears as different realms: the earth and the sky. This demarcating line is correlated with the discontinuity between different states of matter: liquid and solid on the one hand, and the gaseous on the other. The lower sky is the dominion of the air, the gases lighter than the rest of the elements that cannot rise above the surface. Lighter, less dense, they are more loosely bound to one another, freely flowing, swirling, forming a soft breeze by their movement, or violent tempests vigorously caressing the face of the planet. They may pass through our bodies, but they do not need us to explore the ethereal heights. We desperately need them in order for the machinery of our body to function, but they do not need us. They go on their path, from the glacial clouds to the inflamed rivers of magma of the mantle, passing through us but not depending on any of us. Laden with few particles, they float above us, and may even sometimes leave our planet altogether, exploring the emptiness of the cosmos.

The examination of these elements is not only a dialogue be-

tween us and the earth. It is also an encounter with the air and the sky, one that can show us that we are equally made of these seemingly intangible substances forming the clouds and the winds, as much as we are of the earth. Men, and all other branches of the tree of life, are sons of the earth and the sky. To accurately fathom our nature is to feel our belonging to what is above as well as what is below, and the following exploration should bring us closer to both, showing us that we are air as much as we are earth.



2.1 Sulfur

Where the stony skin of the earth is particularly thin, the incandescent blood running underneath imparts some of its inconspicuous fury to parts of our world. Water infiltrating the deep ground, slipping into the minuscule pores of the rocky garment of the planet, may then find itself enriched by such an improbable encounter. It may indeed receive the offerings of the mantle, elements dissolved in it as it circulates through the lightless entrails of the soil, in addition to being brought closer to its boiling point, causing it to ascend to the surface due to its lesser density, sometimes even rising up in the air, in a splendid explosion of vapor and scalding water, better known as a geyser. Approaching such a rare curiosity of nature, we shall immediately be struck by a pungent odor, a displeasing stench reminding that of rotten eggs. Omnipresent in the lands harnessing such water snatched from the grip of the subterranean fire, bringing it to the heart of every home, flowing on the bodies of all men and women as they shower themselves with this present of the depths, this easily recognizable smell is the smell of a particular element: sulfur.

As indicated by our capacity to detect the presence of mere traces of sulfur with our olfaction, it not only finds its way in the liquid of life, but also in the celestial aether, floating above our world.¹ Visiting such a place, doorway to the blazing underworld, or simply remembering this distinct smell, we are invited to reflect

¹Volcanoes, hot springs, and decomposing organic matter release sulfur-containing compounds such as hydrogen sulfide (H_2S) and sulfur dioxide (SO_2) into the air.



Figure 2.1: *Sulfur*.

on the path taken by this element, having been excavated from the depths of the ground thanks to the force of the rivers of molten rock running underneath our feet. They have released this gift in the air, allowing it in due time to reach the four corners of the planet, and to become part of life. Let us reflect on the unpleasantness of its smell, recognizing why life has made it repugnant to us. Present in every living thing, its release in the sky by them indeed is a sign of the decomposition of life, the breaking down of its order. This odor is intricately linked with death and danger, the putrefaction of the building blocks of a creature, explaining why we instinctively flee its presence. Not merely ruled by our primal instincts, but endowed with a capacity to fathom the nature of our surroundings, notably thanks to the agency of this element, we may thus acknowledge the usefulness of our natural aversion to its presence, helping us prolong our days upon the earth, avoiding diseases and poisoning.

Volcanoes are also among the sources of sulfur, and the bright, yellow tint of this substance may be observed on the borders of their vents. Eruptions may bring large quantities of it into the sky, as plumes swiftly joining the clouds, dispersed throughout the globe. Having united its essence with that of the clouds, this element mingles with vapor, and when the heavens empty their storehouses upon

Sulfur

the ground and the seas, it becomes a corrosive substance,² eroding the rocks it touches, but also attacking the skin and the leaves it comes in contact with, if concentrated enough. In minute quantities, it nonetheless fertilizes the soil wherein it penetrates, no matter whether it comes from the air or the ground, regardless of whether it was given by volcanoes, by the weathering of rocks, or directly by the hand of man. The weavers of sunlight absorb it from their roots, and it soon forms some of the most common building blocks of their bodies, being an essential component of the molecular servants of life, proteins, pieces of machinery that can manipulate, assemble, and organize nutrients into the functional parts of a living being.³ Eaten by livestock or wild creatures, themselves subsequently consumed by man, sulfur thus finds its way within our flesh, playing similar roles.

One of the peculiarities of the sulfur atom rendering it invaluable to life is its capacity to form bonds with another of the same kind,⁴ allowing the creation of larger, chain-like structures, stable and resistant, to both movement and change in their environment. Our hair, nails, and skin employ such bridges built with this progeny of the earth, brimstone born out of the flaming blood of the planet. The endurance of our hair, stricken by the sun, stroked by our hands, disheveled by the winds, is due to the nature of this element, found all over our body, concealing its stench by being encased with numerous others, prisoner and servant of our flesh, allowing us to resist the unceasing assaults from the heavens, life, and the earth. Gently passing our fingers through our hair, in our beard, on our eyebrows, or on our skin, paying attention to the way they marry resistance and flexibility, we shall realize that sulfur plays a central role in these marvels discovered by life. Wielding the strength of the blazing depths, the middle realm uses this element to conquer the face of the planet. Acknowledging this fact, let us appreciate these parts of us, and if we fail to believe in the presence of this element there, we may bring one of our hairs to a flame, and then the pungent smell will reveal the truth, indubitably attesting to its presence within

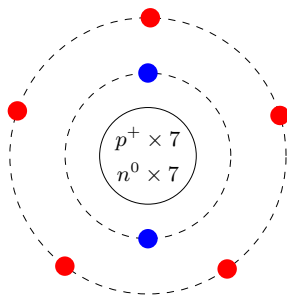
²The release of sulfur dioxide into the air leads to the formation of acid rains, containing sulfuric acid (H_2SO_4). The reaction is as follows: $\text{SO}_2 + \text{O}_2 \rightarrow \text{SO}_3$; Then: $\text{SO}_3 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4$.

³Sulfur is present in 2 of the 22 proteinogenic amino acids, the building blocks of proteins, the pieces of machinery of life. These are: cysteine and methionine.

⁴For example, cysteine molecules can form disulfide bonds ($-\text{S}-\text{S}-$) and form the sulfide derivative cystine, playing an important role in the structure of many proteins.

ourselves.

Sulfur is nonetheless traditionally associated with fire, pain, and chastisement, rather than the fostering of life, and not without reason. This element indeed holds a dual power, both nurturing the growth of life and damaging it. Necessary to life, it can also reveal itself to be toxic to it, like a medicine becoming a poison if used inappropriately. It is a double-edged sword of the earth, placed into our hands, with us free to use it as we see fit. Mined by unlucky souls, condemned to see their flesh eaten by this corrosive substance, brimstone was used early on in our history to whiten cloth. Burning with a blue flame, producing abundant smoke, it was also a trick used by the alchemists to impress the ignorant, and its fumes were recognized as able to exterminate pests in buildings and ships. Even today, it is a common ingredient in the products used to repel and kill the small creatures feasting upon our fields and orchards. It is used in our food to prevent the growth of bacteria and fungi, allowing edible products to be stored for long periods of time. What brings life may also take it. Sulfur fertilizes the ground, but it can also trim entire branches of the tree of life. The devastation that this gift of the earth can bring is nonetheless not limited to insects, molds, and pests. Man has learned to wield this fire from the earth against his own brethren, and even against himself. Large rivers of blood have watered the ground since he discovered firearms, piercing skin, breaking bones, using metals propelled by an explosion. Standing next to such a weapon of war, a potent enemy of life, as its metallic projectile flies through the air to reach its unfortunate target, the odor carried by the flames coming out of it can be unmistakably identified. It is the odor of the brimstone robbed from the dark veins of the earth, the yellow powder coating the flanks of volcanoes. Pondering what we make of this wealth of the earth, using it to foster the growth of life or to hasten its withering, let us make a pledge to wield this power wisely, knowing and respecting its colossal but terrifying power.



2.2 Nitrogen

When we turn our gaze away from the earth, toward the immensity of the sky illuminated by the warm brilliance of the daystar, we see an emptiness, contrasting with the fullness of the realm under our feet. Taking a deep breath, feeling the breeze caressing our cheeks, we are aware of the fact that this emptiness is nonetheless only apparent, and that we draw from this transparent storehouse one of the substances that is the most precious to our body, oxygen. Bits of energy setting the machinery of our cells in motion through a play of attraction and repulsion of matter, gift of the light-workers who produced it during entire eons, long before we arose out of the fluid clarity of the ocean, this invaluable fruit of life still only represents a meager portion of the essence of the lower heavens enfolding our planet. The major part of the content of this open coffer of life was not crafted by the living. It is rather the lingering breath of the earth itself, winds that escaped the depths through cracks and wounds in the skin of the old planet, fleeing to the heights but failing to escape the far-reaching power of attraction of its massive body, made of an element bearing the name of nitrogen. Many other substances were introduced in the sky through similar channels, but most of them were soon returned to the earth or appropriated by life, swiftly reacting with the great variety of particles floating in the air or covering the land. In contrast with them, nitrogen is remarkably obstinate in its refusal to depart from the heights. It strongly binds itself with another atom of the same kind, remaining coupled with its own kind, rejecting the attempt of most other substances suspended in the lower heavens or lying upon the ground to marry themselves with it. Extremely stable, impassive as it encounters countless other bits of matter and is repeatedly caught in the unceasing swirling of the zephyrs, it thus remains while others slowly disappeared, now

representing the major part of the garment of air clothing the earth. Feeling the air entering our chest, or slipping between our fingers, we shall be aware of the fact that we come into contact with this inconspicuous substance. It enters us but also departs from us as we exhale, having left no trace of its passage in our body or upon our skin, utterly indifferent to it, completely ignorant of any way of harnessing its strength or exploiting its peculiarities. We are enshrouded by it, and yet seldom notice its presence, but now, let us take a moment to notice this discreet element, part of our life.

The transparent flesh of the heavens is nonetheless more than a mere piece of the background of our existence. It plays a central role in our bodies, in life as a whole, and the first spark of life may not have been kindled if the heavens themselves did not directly intervene to offer us this mysterious substance. Locked by the strength of its attachment to itself, without walls or doors, this wealth of the sky indeed required an incredible force to be made available to the nascent fire of life. This force came in the form of thunderbolts, the flashing rage of the heavens accompanying anthracite-colored clouds heavily laden with water, a vanguard of blinding light followed closely by a deafening roar, shattering the most intricate bonds between elements found in its flaming path. Punctual and highly localized, thunder may transform nitrogen gas (N_2) into ammonia (NH_3), a liquid whose pungent odor can be detected by our nose where urine has flowed, a sign of it being part of our bodies. This ammonia, offered in minute quantities by the heavens, was enough to allow it to be harnessed and become one of the fundamental building blocks of life. From the dawn of the middle realm, this element thus became part of the characters with which the book of life was written, the book formed by the long chains defining the peculiarities of each being found within each cell,⁵ and also part of the molecular servants building most of the machinery of life.⁶ The

⁵That is, the DNA molecule, abbreviation of deoxyribonucleic acid. The genetic code of all living things is encoded in such a molecule. For more information, see: Lenton, Timothy M., and Michael J. Benton. *Biological Innovations that Built the World: A Four-Billion-Year Journey through Life and Earth History*. Springer, 2019. Pages 65–68.

⁶That is, proteins, molecules that can be very large and perform complex manipulations on the matter coming into contact with them, due to the patterns of attraction and repulsion of their components and the particular way they are folded upon themselves. These patterns and shapes cause them to react with particular substances, like a key inside a lock. Many crucial functions of life depend on such molecular machines. For more information, see: Nelson, David L., and Michael M. Cox. *Lehninger Principles of Biochemistry*. 4th ed., W. H.

infrequent the flashing rage of the heavens nonetheless sufficed to kindle the first sparks of life and fan it into a blaze propagating in the ocean, but it soon proved to be a limiting factor to its growth. Life, eager to explore the possibilities offered by its nature, then grew impatient, desperately waiting for thunderous clouds and their luminous bolts that would unlock the hidden riches of the heavens. It therefore labored, during innumerable years, to discover a way to perform this arduous work by itself, and it one day succeeded in severing its dependence on the benevolence of the celestial forces for its flourishing, through a patient work of selection. Within the walls of certain bacteria, a complex compound was discovered, meticulously laced after countless attempts, one that had the peculiarity of being able to unravel the tight bonds uniting atoms of nitrogen, allowing them to finally be used by life without relying on the generosity of the heavens.⁷ This represented an important milestone in the evolution of life, from a curiosity emerging between earth and sky to a full-fledged realm appropriating the resources from above and below to drive a wedge between them, becoming a third force, standing up to them both.

Even though eons have passed since the uncovering of a way to make use of the celestial nitrogen, rare are the descendants of these creatures, still mastering this arcane knowledge of the unlocking of the major part of the heavenly wealth. Yet, they are very much present in our world, and are essential to the growth of many light-workers. A large part of the tree of life thus rests upon them. They may be encountered in the root nodules of legumes like peas or beans, with these nodules providing a secluded location where they can work their alchemy in the secrecy of the earth, a necessary precaution, as the presence of the other kind of riches stored in the sky, the one we breathe, would prevent these magicians from performing their art.⁸ Digging the ground, observing such globular laboratories of life, we may reflect upon the role played by these invisible creatures for the benefit of the entire tree of life. The nitrogen found

Freeman, 2004. Pages 75–115.

⁷This is known as “nitrogen fixation.” The nitrogenase enzyme produced by certain bacteria, a complex protein serving as a catalyst for chemical reactions, can reduce diatomic nitrogen (N_2) to ammonia (NH_3), which can be absorbed by plants. This allows life to access the abundant reserve of nitrogen found in the air. For more information, see: Schlesinger, William H., ed. *Global Biogeochemical Cycles*. Academic Press, 1992. Pages 263–284.

⁸These are called diazotrophs, organisms such as bacteria or archaea that can transform diatomic nitrogen (N_2) into ammonia (NH_3). In the root nodules of legumes, the bacteria performing this transformation are called rhizobia.



Figure 2.2: *Liquid Nitrogen.*

within our bodies, used to inscribe the very essence of our being deep in the core of each one of our cells, the ink of the calligraphy of our existence,⁹ was prepared by such living beings, humbly working in the ground, unraveling bonds and weaving others, transforming the gifts of the earth stored in the heavens.

Plants are nonetheless helpless by themselves to exploit the most abundant substance of the skies. They do not only rely on a single kind of bacteria to feed them with this celestial substance, but rather on a community of beings, laboring in unison for the elevation of life. The first beings interlace hydrogen atoms together with nitrogen, forming ammonia (NH_3), and then others feed on this ammonia to sustain their own existence, rejecting nitrite (NO_2^-) as a byproduct of their work, which is itself passed on to a third creature, who adds another oxygen atom to it, resulting in the creation of nitrate (NO_3^-), a substance that can be absorbed and used by plants.¹⁰ Each link of

⁹Nitrogen is present in all nucleotides, also called nitrogenous bases, which are the “characters” with which the genetic code is encoded in DNA molecules. These nucleotides are: adenine (A), cytosine (C), guanine (G), thymine (T), and uracil (U). For more information, see: Nelson, David L., and Michael M. Cox. *Lehninger Principles of Biochemistry*. 4th ed., W. H. Freeman, 2004. Pages 75–115.

¹⁰The first step, nitrogen-fixing, is performed in root nodules by bacteria such

Nitrogen

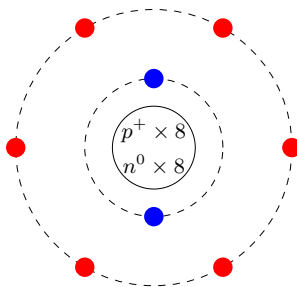
this chain is not conscious of its role in the grand scheme of life. It labors for its own survival and perpetuation, but life found out that such unwitting communion best benefited the whole they form. With each bite we take when we eat, we ingest the work of these precious, minute organisms. We receive the product of their alchemy, and are sustained by their remarkable discovery of a way to unlock access to the prodigiously abundant wealth of the heavens. Each one of our cells is replete with their masterworks. An expression of gratitude toward these humble beings should thus not appear strange to us. We owe them our existence, and each one of our defining features has been written with the ink they produced.

Our body nonetheless does not construct only using the gifts of the earth. It has also learned to return them to the ground whence they came. Our organs can dismantle the complex pieces of machinery that employ nitrogen, breaking them down and evacuating what remains of them through the bodily fluids flowing out from the tube that we form. Furthermore, when the fire of life is extinguished from a creature, and it is reclaimed by the ground, minuscule beings promptly feed upon the ruins of its body, and they meticulously deconstruct the substances composing it into more rudimentary ones. The book of life stored within each cell is thus erased, first turned into a disorderly pile of characters, and then broken down further into the very ink wherewith these characters were written, into nitrates and ammonia, then released back into the soil. We may imagine our flesh, now allowing us to feel and itself the subject of our sensations, being disassembled by the tiniest of all creatures, dwelling in the sooty ground, embracing the roots of the diligent braiders of sunlight laboring for the elevation of life. The very book of life that defines what distinguishes our body from that of all the other living things inhabiting this planet, reproduced in each one of our cells, shall in a few years be dissolved into the letters with which it was composed, before it either once again slips into the roots of a light-worker, enters the mouth of a worm or insect, or evaporates and returns to the celestial storehouse, among the billowing clouds, bathed in celestial brilliance. From there we came, and there we shall return, part of a great whirlwind of nature, passing through

as rhizobium. The second step, nitrification, that is, the conversion of ammonia (NH_3) into nitrite (NO_2^-), is done by bacteria such as *nitrosomonas*. Finally, the transformation of nitrite into nitrate (NO_3^-), directly usable by plants, is performed by bacteria like *nitrobacter* or *nitrospira*. For more information, see: Schlesinger, William H., ed. *Global Biogeochemical Cycles*. Academic Press, 1992. Pages 263–284.

the earth, life, and the sky, across the ages.

Having pierced the mysteries of the content of the heavenly coffer, and appropriated its nature, man also took upon himself the task of wielding this new tool at his disposal for the strengthening of his yoke upon the realms of nature. Fabricating prodigious quantities of nitrogen compounds, extracting the substance of the air and weaving it with other elements, man scatters these compounds upon his fields, sowing this element like seeds, to stimulate the growth of the light-workers, thereby increasing this resource he can exploit for his own benefit. Catching the winds, merging their essence with the essence of the ground, he inflates the body of life, as he aggrandizes himself. He sees the breadth of his world, the extent of his dominion considerably enlarged, with sometimes disastrous results, as he wreaks havoc upon other branches of life by his habitual carelessness and his insatiable greed. Watching the fields with their ripe crops in the open country, the stalks balanced by the winds, the sun and the rains abundantly feeding them with radiance and the limpid liquid of life, we may notice how the skillful hands of our brethren have played a crucial role in their growth. These winds have been channeled and exploited for this purpose by mankind. These winds not only blow around these plants; they also blow *within* each one of these grains, these leaves, and they circulate within every creature feeding upon them. The breath of the earth, softly blowing upon our face, is also our breath, our flesh, what we are now. It runs through every part of us.



2.3 Oxygen

No matter whether we sleep or are awake, whether we laugh or cry, whether we live in squalor or in the most obscene luxury, we, for now at least, all equally share a resource stored in the sky upon which our bodies entirely depend, as our existence is paced by the rhythm of our breath, instinctively drawing this invisible substance from the air. We may survive for a month without ingesting the fruits of the light-workers or the flesh of animals, and a few days without alleviating our thirst with some of the clear liquid of life rained down from the heavens, but mere instants of deprivation of this breath of life would be sufficient to mark our last day upon the earth. We live because of this free access to the riches stored in the lower heavens, but we should remember that they have not always been there. They were not placed there by the activity of the earth or a manifestation of the celestial forces. They are rather a product of the light-workers, a colossal reserve of what they had no need of, and first rejected away from them, before other branches of life, like animals, found out the hidden power of this substance found in the air, allowing them to sever their dependency upon the rare gifts of the earth,¹¹ to instead feast upon this seemingly infinite cloud of energy.

The breath of life now filling our lungs, oxygen, was first imprisoned in the earth, in the form of the water forming the oceans. The

¹¹Before the great oxygenation event and an abundant presence of oxygen in the oceans and the air, life relied on substances coming out of hydrothermal vents and volcanoes, such as hydrogen sulfide (H₂S) or ferrous ions to transform nutrients into usable compounds. Such organisms, still present in these peculiar locations, are called anaerobes. For more information, see: Willey, Joanne, Linda Sherwood, and Christopher J. Woolverton. *Prescott's Microbiology*. 7th ed., McGraw-Hill, 2008. Pages 205–207.

emerald beings that covered the shallows of these bodies of water then learned to perform a formidable feat, wielding the force of the sun, employing the luminous envoys it showers upon land and seas, to shatter the bonds between the elements forming water, oxygen and hydrogen. Spears of fire are driven deep into the heart of water, releasing the strength captured by these bonds, then harnessed by the living to power the machinery of their lives. The hydrogen thereby liberated is then used to build complex substances like sugars, used as fuel, while the oxygen is simply discarded, abandoned to float in the sky, useless to them. As myriads of beings performed this meticulous work during a considerable number of years,¹² the heavens were slowly transformed by the unceasing accumulation of this new celestial vapor. Corroding and reacting with what it touched, it soon proved to be a danger to many branches of the tree of life, which had to adapt to this novel environment or perish. One of them, a mere bacterium, soon discovered that this new wind could be used to transform food into usable energy, far more efficiently than the methods employed at the time.¹³ Enslaved by our ancestor, captured within its walls and condemned to serve it, such bacterium soon became part of our bloodline, and its descendants still to this very day inhabit each one of our cells, allowing us to exploit the wealth of the sky to animate our flesh.¹⁴ Taking a deep breath, feeling the celestial aether fill up the deepest parts of our chest, we may acknowledge the invaluable contribution and prodigious ingenuity of this minute creature, now part of us. Carried in our blood as it is absorbed in our lungs, this breath of life reaches each one of these servants of our being. The birth of a creature as massive and complex as us would not have been possible without their discovery and their diligent service. Let us thus pay homage to this humble branch of life, now intertwined with us, even though it has preserved the

¹²The great oxygenation event lasted around 400 million years, beginning around 2.5 billion years ago and ending around 2.1 billion years ago. For more details about this event, see: Lenton, Timothy M., and Michael J. Benton. *Biological Innovations that Built the World: A Four-Billion-Year Journey through Life and Earth History*. Springer, 2019. Pages 129–154.

¹³Before the discovery by life of aerobic respiration, that is, the use of molecular oxygen (O_2) to transform nutrients into usable energetic molecules (like ATP), living organisms used anaerobic respiration, using compounds like nitrate (NO_3^-), sulfate (SO_4^{2-}), or fermentation, which uses enzymes to break down nutrients and transform them into ATP.

¹⁴This organism, now part of us, is the organelle named mitochondria. It possesses its own genetic code, distinct from the rest of our body, known as mitochondrial DNA. For more information, see: Alberts, Bruce, et al. *Molecular Biology of the Cell*. 6th ed., W. W. Norton & Company, 2014. Pages 755–762.

Oxygen

uniqueness of its book of life, present in our cells, distinct from the one telling the story of the rest of our body.

Once the breath of life has been exhausted by our cells, it is mainly transformed into water, exhaled as a warm vapor swirling out of our lungs, or evacuated through our urine. Our respiration nonetheless also returns to the sky the oxygen it received in a different form. Indeed, when our food has been digested and its nutrients fully used by our body, what remains of them is broken down, and pieces of them are also discarded through our lungs. Among these, we find carbon dioxide (CO_2), a substance containing oxygen, crucial for the existence of the light-workers, using it as fuel just as we use what they discard. We breathe out this vivifying carbon wind, craved by the weavers of sunlight, and thus a fruitful equilibrium was born between the moving beasts and the light-workers, between animals and plants, each feeding on what the other produces as a byproduct of its existence. The breath of life is thus interlaced with the carbon winds, just like our fate is inextricably bound to the fate of the emerald beings. Taking another deep breath, letting it flow out of our mouth or nose, we can imagine that we are thereby offering back something in exchange for what we have received. The lower heavens are a precious reserve shared between us, the moving creatures, and our distant cousins, the light-workers, with the breath of life and the carbon winds containing the same essence running through us and between us. Feeling the winds, feeling our breath, we experience this vivifying trade, this exchange essential to us both.

High above the summit of our world, in the desert heights inaccessible even to the clouds and the winged lords of the sky, the vanguard of the earth, facing the blinding radiance of our star, sees its nature altered by this luminous presence. Bits of the breath of life thus stand there, isolated, and as they encounter the fiercest of all the envoys of the sun, the bonds uniting the atoms of these elements, in pairs, are violently severed. The force of this collision causes them to subsequently bind themselves in groups of three, forming another substance, with unique properties, known under the name of ozone (O_3). Forming a layer of distant bits of matter surrounding the globe, it intercepts and absorbs the dangerous spears of fire thrown by the sun, preventing them from damaging the life covering the earth. Born out of life, these bits of matter now stand as a shield defending their parent, accepting to be subject to the enmity of the star to spare those living upon the surface, far below. Floating on

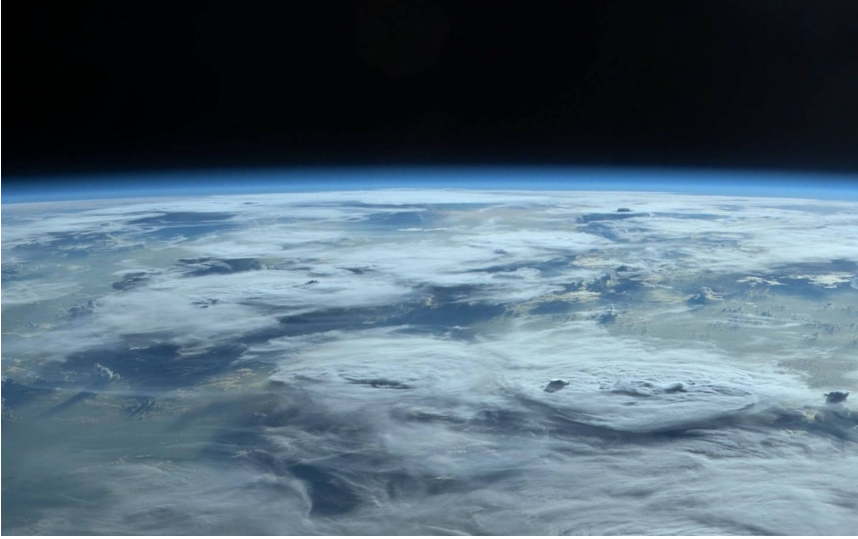


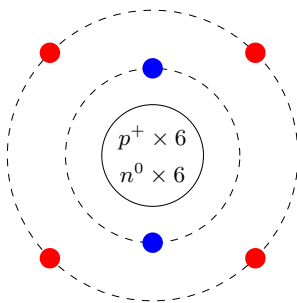
Figure 2.3: *The ozone layer.*

the edge of our planet, barely feeling the pull of the earth, this celestial armor is still arrayed above us. Turning our gaze upwards, let us contemplate this imposing and yet remarkably light shield enveloping our world, imagining with what force the sun would strike us without its presence, perhaps burning our skin or damaging our eyes. From the deepest abyss to the ethereal peaks of our planet, this element we breathe forms an essential part of our existence, too often forgotten or overlooked. But this is a chance to better appreciate our bond with it.

The breath of life nonetheless first arose from the flaming entrails of the earth rather than the ethereal heights. It was first prisoner of the mantle before it was released as the steam that later condensed to form the oceans. But some of it obstinately remains there, encased in the rocky ground, and part of it returns to it after having enjoyed the freedom of the skies and servitude to the living. The crimson rust covering the objects of our world left exposed to the breath of life blowing in the sky represents such a return, as the metal binds itself to the essence of this breath, giving it the same hue as that of our blood. Many other substances react with this breath, capturing it and taking it back to the ground, as they are themselves carried back to the shadowy inferno beneath our feet. Plunging into the mantle, put under phenomenal pressure and thrown into the earthly crucible, some of it will be turned into new minerals, sealed

Oxygen

in stone. Brought back to the surface by the rivers of magma running under our world, they may one day reappear in our world, as magnificent stones. Beholding the violet tint of an amethyst, standing in awe of the enthralling colors of an opal, or contemplating the soothing, blue warmth of a block of lapis lazuli, this beauty is the result of the capture of the breath of life. These elements may have been exhaled by an ancient being, perhaps one of our direct forefathers, and one day, the air we exhale now may also be turned into gemstones and crystals, adorning the neck of our distant descendants. Reflecting upon the greatness of the course of this element, central to our world, essential to our life, we shall be grateful for its presence, all around us, letting our chest receive this present of the earth, life, and the sky.



2.4 Carbon

Life is an astonishingly sophisticated construction, towering high over the earth, made of colossal quantities of minuscule and yet incredibly complex substances, folded upon themselves, acting like machines able to manipulate, create, or disassemble. Various elements play a part in this mysterious realm of nature, but few have a more central role than carbon, representing the very frame of life. It is no mere coincidence that this element is omnipresent in almost every part of living things. It is rather due to its capacity to bind itself to four other atoms, including those sharing with it its nature, allowing it to form long and convoluted chains, each with singular properties that were meticulously experimented and selected by life during its long and glorious history. Scaffolding of the living, it is what remains when the flames have consumed most of their substance, having chased away all moisture to the heavens. The tree becomes a pile of coal, and the beast a charred carcass, dead earth. The wide palette of colors displayed by the skin, fur, petals or leaves of the living then fade to an identical shade of black, the bloody flesh and the sappy wood equally becoming friable chunks of dry matter crumbling under one's fingers, leaving dark marks upon what they come into contact with. Burning a piece of the middle realm, such as a leaf freshly fallen from a tree, watching it combust and crumple, submitting to the power of fire, we may observe the lifting of the veil covering this scaffolding of life. Letting the sooty product of this puzzling phenomenon leave its imprint upon our fingers, let us realize that these appendages, and our entire body, are equally made of this strange and extremely versatile element. It is the heart of the pencil wherewith we describe our world on paper. It is the shiny diamond extracted from the obscure entrails of the earth to

adorn the hand of our betrothed, and it is the fuel that powered the construction of large sections of our world. Standing up, straight, pointing heavenward, our whole body is held together by the bonds braided by this element. If they were to suddenly be unraveled, our flesh would, without delay, be spread upon the ground like the contents of a bucket of water and blood, swiftly absorbed by the soil.

Man is nonetheless merely a brief stop for the carbon forming his frame. It comes and it goes, passing through the realms as the ages succeed one another, left unaltered by this passage, remaining faithful to its nature, given to it by an ancient star, whose ashes now form the celestial bodies around us as well as ourselves. Gathered by the planet, thrown into its spherical furnace, part of it is allied with calcium to form limestone and marble¹⁵, finding its way to the surface after having been patiently kneaded by the hands of the earth. Another part finds itself bound to a lighter element, the breath of life, oxygen, and thus its lightweight nature allows it to slip through the wounds of the planet, escaping its blazing blood, to discover the heights of the sky, floating as a carbon wind blowing over land and seas.¹⁶ But this wind is far from lost to the dwellers of the earth and the seas. On the contrary, it is when it has been liberated from the rocky ground; when it has escaped from the smothering embrace of the earth, that it can prove itself useful to the middle realm. Beholding how the plants take root, deep in the soil, as they collect the celestial brilliance through their jade-colored leaves, blades, or needles, one may easily be inclined to think that they extract the essence forming their body from the variety of substances found in the ground; but one would be mistaken. Contrary to our intuition, the frame of these light-workers is constructed with the air rather than the earth, with the winds rather than the soil. Observing how the grasses and the trees rise up from the ground, extending their arms toward the luminous fountain of radiance circling the celestial vault, caressing them while we feel the wind passing on our face, we shall grow aware of the link uniting these living things to the sky. This wind penetrates the minuscule emerald doorways covering these leaves, and it offers the carbon it contains to further the building of these humblest of all beings. What we touch is a child of earth and sky, light and air married with soil and water,

¹⁵Both limestone and marble are composed of calcium carbonate (CaCO_3), with marble often having a certain amount of impurities giving it its veins and colors.

¹⁶This carbon wind is carbon dioxide (CO_2)



Figure 2.4: *Coal.*

with the heavenly carbon serving as the scaffolding of it all. A pillar built with air, resting upon air, such are the majestic trees adorning the face of our planet. They breathe in these carbon winds, unwinding the bond between carbon and oxygen, using the former as a building block while discarding the latter back into the air. Brick by brick, their body is constructed with this element, interlacing it with others, braiding long chains considerably thinner than the lightest silk, each with a precise purpose, defined after countless refinements across innumerable generations. Let us take a moment to value this astounding discovery made by life itself, allowing the air to almost magically be turned into living things.

When we and the other animals dwelling upon the dry land feed upon these weavers of air and light, we undo their meticulous work, unraveling some of the bonds woven by them to use the building blocks of these beings to further the construction and fortification of our own bodies. As each one of our cells breathes the breath of life entering our lungs and flowing into our blood, it uses its energy to liberate the strength encapsulated in some of these ingredients of the living, and incidentally, they breathe out a carbon wind as a byproduct of this reaction.¹⁷ Exhaled by our lungs, this carbon wind

¹⁷Our cells absorb glucose, and in the presence of oxygen coming from our lungs, they transform this glucose into ATP, which powers most processes of our

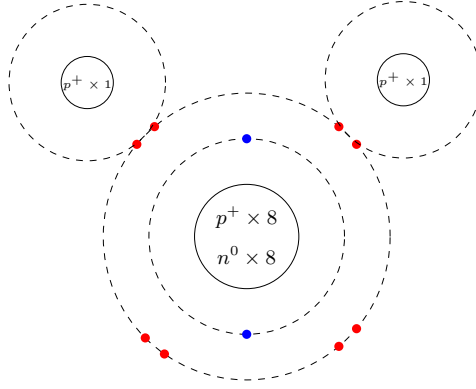
Carbon

returns to the heavenly storehouse, available to the light-workers who crave it for their growth, and thus plants and animals find themselves inextricably bound together by this ethereal substance. What one craves, the other graciously offers, and the two branches of the tree of life find themselves strengthened by this fortunate braiding. Standing in front of a luxuriant forest, a flowered meadow, or a wide grassland, we can see ourselves in a continuous dialogue with these emerald beings. They feast upon our breath, and we are vivified by theirs, without seeing the faintest trace of this link in the air. But we now know of this interweaving of our nature. We are now fully aware of our interdependency, and thus we shall express our deepest gratitude to the industrious beings forming this green vestment clothing our lands. Breathing out, we offer them the means of their future growth. Breathing in, we receive from them the gift of a few more instants of existence, above the earth rather than inside it.

Notwithstanding the profusion of invaluable gifts offered to us by nature, we shall still one day cede our place to a new generation. Our bodies shall ineluctably crumble, and our progeny shall stand upon our ashes, their world reaching new heights because of both our contribution and our departure. On this fateful day of our last breath, our last present given to the light-weavers, the frame of our being shall be scattered in the soil, if it is spared by other living things. The ruins of past lives thus find themselves buried, deeper and deeper as new layers are piled upon them year after year, until so many years have passed that these ruins have been stripped of many of the substances clothing them, and all that is left is the carbon frames, scaffolding of their being, pressed by the earth above them. Thus were ancient forests turned into sooty oil buried deep in the ground, into coal or tar, according to their surroundings and the length of their sojourn in the depths. Bringing a flame to these ancient ruins, their origin is nonetheless unmistakable: they brightly burn, their essence turned into warmth and light, just like the trees and the grasses now growing in our world, and unlike most of the ground made of minerals, largely insensitive to fickle flames. Watch-

bodies, and the resulting byproducts of this reaction are carbon dioxide (CO₂) and water (H₂O). This reaction can be written as: C₆H₁₂O₆ + 6 O₂ → 6 CO₂ + 6 H₂O + ATP. The carbon dioxide produced during this reaction diffuses out of the mitochondria, passes into the blood and is carried to the lungs, where it is finally exhaled. For more information, see: Campbell, Neil A., and Jane B. Reece. *Biology*. 8th ed., Pearson Benjamin Cummings, 2008. Pages 915–922. (Chapter 42.5–6).

ing a piece of such remains of life being consumed, turned into smoke rising in the sky, we behold the essence of an ancestor or cousin being liberated, escaping its earthly tomb to once again float in the heavens, where it shall soon be snatched by a new living thing, becoming part of it, resurrected by the contact with a source of incandescence. Each atom of carbon concealed within our cells has probably performed such a marvelous journey, from the heart of a star to the surface of a leaf, and then back to the smoldering abysses of the ground. We may share part of our frame with the very first living thing that emerged from death, when the earth was still a planetary newborn, barely solid, and parts of it may one day be found in a radically different world, different beings, and they shall still be there the day all of it will end. Feeling this unity between us and all other living things using this element, let us offer them our breath, as a blessing coming from the bottom of our chest.



2.5 Water

It was relatively frequent for wise men of ancient civilizations to mistakenly consider water to be a fundamental element of nature rather than a compound substance, and this not without good reason. Water indeed occupies a central place in the living realm. Most of our bodies is water.¹⁸ It is found in every limb, every organ, every cell, and without it, we would crumble like a leaf parched by the radiant summer sun. A lack of the liquid of life is immediately felt by our senses. Our lips begin to dry up and crack, and saliva becomes scarce in our mouths. But more than this, we can feel one of our deepest instincts guiding our footsteps, as we are naturally led to desperately seek a source of the precious beverage, knowing in our bones that a failure to discover a source may imply certain death in a matter of days. Let us recall a moment in our life when we intensely craved this transparent liquid, having felt the danger of its absence, and experienced the bliss of finally seeing our thirst quenched. We have let fresh water run down our throats, which was then securely stored in our belly, before it became an indistinguishable part of us. Touching our flesh, feeling its flexibility and softness, we may there recognize some of the peculiarities of the liquid of life. It flows through us, pervades us, and if it remains part of this vivacious water-skin that we are, it is because the rest of our body has learned to jealously keep it, imprisoned inside impermeable walls of skin, condemned to serve the purpose of our existence. We may

¹⁸The proportion of water declines with age. The body of a newborn is around 80% water, whereas it may only be around 50% for a person reaching old age. For more detail, see: Lu Hong, et al. *Body water percentage from childhood to old age*. Kidney Res Clin Pract. 2023 May. Pages 340-348.

rightfully wonder why this abundant fluid forming the seas and the clouds is so essential to all the living, and the answer would be as limpid as water itself: its role comes from its remarkable capacity to carry all sorts of substances dissolved in it. It acts as the minute hands of life, favoring interactions between bits of matter, bringing them into contact or transporting them away. It is the oil of the machinery of our body, what allows every one of its pieces to be set in motion. Imagining what goes on right now inside our skin, we may envision these infinitely small droplets running through us, involved in every process, taking part in every action, a medium rather than an essence, as was the ocean before life climbed out of the shallows to conquer the dry land. Let us feel that we ourselves are vessels filled to the brim with this invaluable present of the earth and the sky. A jug of water wherein other substances offered by the earth are dissolved, a water-skin bewitched by a mysterious fire bringing order to it and setting it in motion, this is what we all are.

We are nonetheless but a waypoint in the interminable course of the droplets of water forming our body. Each time we exhale, each time we cry, each time we sweat, or each time we hearken to the call of nature, inviting us to offer some of our substance back to the earth, we let the water that was part of us leave our body, releasing what we had previously captured. Some of it will swiftly be snatched by the winds and brought to join the woolly mass of the clouds hovering above our world. The rest of it will run into the dark body of the earth, laden with legions of elements extracted from the ground itself, scraped from rocks, or robbed from the living. It then seeps into aquifers or flows into rivers, sliding downward to find the great ocean. Drops will spend eons in the depths, in search of the sea, while others will reach it in mere days, carrying treasures to the great blue realm, according to their destiny. Their destination, the ocean, which is balanced by the pull of the moon each day, is the cradle of life, the great reserve wherein the tree of life takes root, with many creatures still calling it their only home, even though we as a species have long deserted it, only looking at its beauty with wonder, perhaps an unconscious sign of nostalgia for our first abode. We no longer need it, because we carry its essence within our skin, but as we plunge ourselves in the great, watery expanse, we may feel a strange communion with this silky medium, seemingly freeing us from the pull of the earth. Swimming in the ocean, floating upon it, we may realize the nature of water, and our own, inextricably tied to it. There, we may consider the tortuous course of what surrounds



Figure 2.5: *Water.*

us, the great and adventurous voyage of this omnipresent liquid. It may have passed through other living beings, men, beasts, plants, or fungi. It may have traveled through a remote continent, visiting the deepest underworld, passing through vast unexplored caves, and encountering the ruins of long-gone worlds.

But while the ocean is the birthplace of life, it is not the birthplace of water itself. This precious substance first came from the depths of the earth, brought up by the torrents of molten rock and metals running underneath our feet, released as steam into the sky, where it soared, becoming a blanket of cottony clouds clothing the rocky planet. This formidable mass of bulging water, reaching the other side of our world, was once entirely floating in the air, above

the then-naked face of the earth. As the blaze of the underworld slowly cooled down, this steam could one day no longer resist the alluring appeal of the ground. Deprived of its rage, it let itself go. It rained down upon the earth and adroitly ran to the lowest ground, to better feel the presence of the heavy core at its center. Playfully throwing handfuls of water into the air, we can see how it immediately and irresistibly returns to its source, but although it now belongs to the lower realm, the essence of the ocean nonetheless remains profoundly heavenly, and it keeps this nature hidden within itself. Water is a subtle marriage of two elements, deeply linked with the heavens, more than the earth. One of them is hydrogen, the primordial element. It is the first to have appeared and the most abundant in the skies, but it is foremost the substance of the daystar. It is the burning of this rudimentary element, its destruction and the fusion of its essence, that we witness when we raise our eyes toward the incandescent orb enthroned in the celestial vault. The other is oxygen, what we crave and take from the air each time we draw our breath, the wealth accumulated there long ago by the first light-workers, now a treasure balanced by the winds, free in the vastness of the sky. As we drink of this water of life, we may see ourselves as absorbing the power of the sun and the power of the winds. We share with them a similar nature, and thus we shall feel a communion between the realms, realizing that they are one, and that we are them.

The celestial nature of water nonetheless does not permanently remain concealed. A few traces of the precious, limpid liquid upon our skin exposed to the open air and the brilliance of the sun would suffice to demonstrate this unwavering loyalty to the sky, as we can watch them grow thinner and smaller, until they fade away completely. One by one, each molecule was separated from others molecules by the celestial forces, and this isolation, this lesser density, caused them to become as light as the air around them, and thus they rode upon the wings of the winds, returning to their old dwelling place, one with the clouds. These cottony mountains passing through our land are towering masses made of the liquid of life, as much as what flows within our veins. The sun and the winds take it up from the ocean, lifting it to the heights, and they bring it above the dry land, the places durably out of the reach of the seas, inaccessible to the strongest tides stirred up by the pale luminary of the night. These forces of nature then release it, letting it fall down gently, drop by drop, upon the deserts and the peaks

Water

of the highest mountain ranges alike. Some will be hardened into ice, frozen and left in place until the sun finally reaches them again, while others will become brooks and torrents, carving entire valleys and canyons. They will run inside cities through convoluted webs of pipes, where men will rejoice at the sight of this transparent, liquid treasure, pouring it into ewers and cups before letting it become part of them. Water thus circles the realms, as it circles our bodies. Caught between two fires, the magma of the earth below and the radiance of the sun above, which turn it into steam, water becomes the liquid of life when it remains on the surface, close to our world, part of ourselves. We are channels through which water and earth flow without the slightest interruption. We are not mere bystanders of the great cycle of water, we are fully part of it. Let us now picture the future paths that may be taken by the water forming our body now. Where will it go? What will it be part of? It may one day be drunk by the sovereign of a future civilization, or stay buried for ages in the deepest aquifer. It may flow through the heart of one of our descendants, or become a juicy exotic fruit in a land far away. It will not keep any memory of us, but we, this curious mélange of water and other earthly elements bewitched by the sacred fire of life, are able to envision its future. If this part of us remains, circulating throughout the realms of nature, will we truly be gone then?

Conclusion

To someone who has been sufficiently attentive while he listened to the story of the earth, the blue planet should now begin to shine in a new light. More than a rigid foundation of man's world, more than a mere reserve of resources to be exploited, it should now appear as a mass of matter continuously transformed by the hands of the heavens, one that, in turn, shapes life like a potter shapes his creations. As he looks at the wounds of the earth, the fissures present upon its rocky skin, he should see the life of the ground, the activity of the soil, reading the superimposed layers of minerals as one reads a manuscript, the great book of the earth. This book is given to all of us to behold and read. It is our inheritance, but also a chronicle of our own past, of the origin of our present nature. If we fail to let this sacred knowledge of the earth, with which we are now familiar, transform our way of seeing, alter our vision, as we look at what surrounds us, it then implies that this knowledge has not been understood, but has only been heard as vain fantasy, disconnected from our common experience of this giant mass of matter under our feet. Each time we draw our breath, we should give thanks to the light-workers who offered us this air. Raising our eyes toward the pale complexion of the moon, we should commemorate the great collision of the two celestial bodies that resulted in the birth of this luminary of the night. Contemplating the oceans, we should see the great deluge that, drop by drop, created this astonishing, translucent vestment of the planet.

To someone who has trodden on the paths of the elements, the body should now cease to appear as something that stands out from the rest of the dead matter forming the planet. It should no longer be seen as something isolated, inherently different from a stone, a blade of grass, or a puff of smoke swirling into the sky. If we succeed in perceiving the course of these paths, we should now feel inextricably

bound to the rest of the greater earth, that is, the ground, life, and the air, all sharing a common substance. Our materiality, our earthiness, should now brightly shine in our eyes. We shall feel the iron from the ground, source of the invisible shield of the earth, flow into our veins. Touching sandstone or strolling on a sandy shore, trampling the remains of mollusks and crustaceans, we shall see in them the bones forming the frame of our body. Shedding a tear of joy or sadness, we shall perceive its fall as a return to the ground out of which it came, a libation, with the vision of its future elevation in the heights of the sky by the blazing vigor of the sun, gathered in an immense cloud, warming our hearts.

As we walk on the straight line as well as the circles, that is, as we look at the past and future horizons of the earth as well as contemplate above and below, as we observe the present course of all earthly matter, the world we inhabit should now appear as fundamentally terrestrial. Our inextricable belonging to this majestic realm, perhaps unique in our universe, should be perfectly clear. The brief exploration of the earth offered by the present work should nevertheless not be considered objective or authoritative. Far from it, it is merely the record of a deeply personal journey, one that should be replaced by an equally personal initiative by the reader. The story of the earth is indeed one that can always be revised, as the march of progress continues and our knowledge is refined or deepened. It is meant to represent a starting point, an invitation. Different from a religious revelation, any attempt to appropriate the truth of the earth should necessarily be subject to a constant reevaluation. If it is found to be erroneous, distorting or not reflecting the reality of nature, it should be thrown away, amended, or written anew. This story is no more sacred than any word coming out of our mouth, but if it reflects a fundamental truth and reveals it to men who will find themselves transformed for the better by it, it is one that is worthy of being told, loudly proclaimed or inscribed in numerous volumes.

The vision we have of the earth and of our place in it should nonetheless not blind us to the remarkable extent of our ignorance. The earth represents our experience of matter itself, as the matter found in the skies remains out of the reach of everyone but a handful of explorers of the cosmos, but it would seem that most of the matter composing our universe remains obstinately concealed from our eyes, and to our science. The substance of our planet, of our bodies, of all planets and stars, is but a small portion of the substance of

Conclusion

the cosmos. The so-called “dark matter,”¹⁹ thus named because it escapes observation by not interacting with light, has yet to be encountered directly, and even its existence is only inferred due to the gravitational effect it has on distant galaxies, and it already teaches us something precious: the fact that we may be fundamentally incapable of perceiving most of the matter surrounding us through the work of our senses. This mere fact should humble us and invite us to reflect on the greatness of the gaps in our knowledge, no matter how proud we are of the achievements of our world. We may be surrounded by things we cannot see or touch, right now, forces or particles that will one day be uncovered. Future generations may therefore enjoy a clearer vision of the earth and of themselves, but no matter the depth or superficiality of our knowledge, we have already been given enough to appreciate the chance we have to enjoy a few years of existence on this wonderful planet, and in this world of contrasts, in constant tension between the sublime and the horrendous. A worm navigating the ocean long before life set foot upon the dry land was not given the opportunity of such a contemplation of the truth of the earth. How narrow was the horizon of our cave-dwelling ancestors, who were endowed with the same capacity to reflect, the same intelligence, but had yet to receive a sufficient inheritance, in the form of words of science and wisdom, to be able to envision the nature of the realm under their feet. The men of a distant future may look at us in the same way, as primitive beings, deprived of a particular truth, and thus we may imagine what is left for life to uncover. But we have yet to face death. We have yet to return to the ground, and thus we may continue to examine this great sphere of rock, metals, life, and air, rejoicing in every day we are given to spend above its surface rather than under it, tightening our bond with it, until we have forgotten ourselves and until there is nothing left, not even the earth itself.

¹⁹For more information concerning dark matter, see: Chaisson, Eric, and Steve McMillan. *Astronomy: A Beginner's Guide to the Universe*. 8th ed., Pearson, 2016. Pages 448–450.

Timeline

A timeline of the major milestones of the history of the earth can be found below, together with the corresponding chapters recounting this period. Due to the fact that our knowledge of our planet is continuously improved and revised as new discoveries are made by investigators of nature, one should keep in mind that these numbers may fluctuate, and that one should therefore not be too attached to them, but should rather focus on the larger picture, the great movement that is followed by our beloved home. This is one of the reasons why such computations are not mentioned in the core text of the present work.

Million years ago	Event	Chapter
13 700 ²⁰	The Big Bang	-
4 700 -4 600 ? ²¹	Accretion of the Earth	Ch. 1
4 700 -4 600 ? ²²	Solidification of The Earth’ s Crust	Ch. 2
4 700 -4 600 ?	Formation of the First Atmosphere	Ch. 3
4 600 ²³	Birth of the Moon	Ch. 4
4 400 ²⁴	Condensation of the Oceans	Ch. 5
4 000 ²⁵	Formation of the First Continent	Ch. 6
2 200 -1 500 ²⁶	The Great Oxygenation Event	Ch. 7

²⁰From: Lutgens, Frederick K., Edward J. Tarbuck, and Dennis G. Tasa. *Essentials of Geology*. 11th ed., International ed., Pearson Education, 2012. Page 466.

²¹From: Ibid.

²²From: Ibid.

²³From: Ibid.

²⁴From: Wilde, Simon A., et al. “Evidence from Detrital Zircons for the Existence of Continental Crust and Oceans on the Earth 4.4 Gyr Ago.” *Nature*, vol. 409, no. 6817, 2001.

²⁵From: Lutgens, Frederick K., Edward J. Tarbuck, and Dennis G. Tasa. *Essentials of Geology*. 11th ed., International ed., Pearson Education, 2012. Page 469.

²⁶From: Ibid. Page 467.

Million years ago	Event	Chapter
717 -635 ²⁷	The Snowball Earth	Ch. 8
165 ²⁸	The Breakup of Pangaea	Ch. 9
0.115 -0.011	The Last Glacial Period	Ch. 10
0.0005 -present	The Anthropocene	Ch. 11

²⁷From: Warren, James V., et al. “Four-Million-Year Marinoan Snowball Shows Multiple Routes to Deglaciation.” *Proceedings of the National Academy of Sciences of the United States of America*, vol. 122, no. 18, 2025.

²⁸From: Lutgens, Frederick K., Edward J. Tarbuck, and Dennis G. Tasa. *Essentials of Geology*. 11th ed., International ed., Pearson Education, 2012. Page 475.

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